Price 1s.

Geological Series
Bulletin No. 14

UNION OF SOUTH AFRICA

DEPARTMENT OF MINES

FLUORSPAR
IN THE
UNION OF SOUTH AFRICA
AND
SOUTH WEST AFRICA

BY

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Publication of the Geological Survey Division

PRINTED IN THE UNION OF SOUTH AFRICA
BY THE GOVERNMENT PRINTER, PRETORIA
1943

P.-S.5183—1942-3—1,500.

CONTENTS

PAGE

ABSTRACT.......... 3

I. INTRODUCTION.......... 3
  A. NOMENCLATURE.......... 3
  B. PROPERTIES.......... 4
  C. STRUCTURE.......... 7
  D. TYPES OF OCCURRENCE.......... 8
  E. THE RELATIONSHIP OF THE COLOUR OF FLUORSPAR TO THE TYPE OF OCCURRENCE.......... 9
    1. Replacement deposits in the Dolomite, Marico district.......... 9
    2. Deposits in the Red granite of the Bushveld Igneous Complex.......... 10
    3. Deposits in alkaline rocks.......... 10
    4. Occurrences associated with tin deposits near Potgietersrust.......... 10
    5. Miscellaneous occurrences.......... 11

II. OCCURRENCES IN THE TRANSVAAL.......... 11
  A. OCCURRENCES IN DOLOMITE.......... 11
    1. Introduction.......... 11
    2. Oog van Malmanie 101.......... 11
    3. Buffelshoek 284.......... 13
      (i) The Zincblende-Fluorspar deposit.......... 13
      (ii) The "Gravel" deposit (No. 3 Quarry).......... 14
      (iii) Blane's No. 1 Quarry.......... 16
    4. Witkop 288.......... 17
    5. Stinkhoutboom 96.......... 18
    6. Small deposits in the Marico district.......... 18
    7. Conclusions.......... 19
  B. OCCURRENCES IN THE RED GRANITE OF THE BUSHVELD IGNEOUS COMPLEX 19
    1. Cyferfontein 1094, Waterberg district.......... 19
    2. Tooyskraal 282, Waterberg district.......... 22
    3. Ruigtepoort (Goudkoppies) 1373, Waterberg district.......... 26
    4. Slipfontein 528, Rustenburg district.......... 30
    5. Vischgat 1091, Waterberg district.......... 32
    6. Buffelsfontein 969, Potgietersrust district.......... 32
    7. Grobbelaars Hoek 785, Potgietersrust district.......... 34
    8. Valschfontein 432, Pretoria district.......... 36
    9. Analyses.......... 36
    10. Conclusions.......... 37
  C. OCCURRENCES IN THE ROOIBERG FELSITES.......... 37
    1. Roodeplaat 314, Pretoria district.......... 37
  D. OCCURRENCES ASSOCIATED WITH ALKALINE ROCKS.......... 39
    1. Occurrences in the Pilansberg.......... 39
      (*a*) Wydhoek 701.......... 39
      (*b*) Nooitgedacht 748.......... 41
      (*c*) Buffelskloof 219.......... 41
    2. Walmansthal 116, Pretoria district.......... 41
    3. Leeuwfontein 320, Pretoria district.......... 41

III. OCCURRENCES IN THE REST OF THE UNION AND IN SOUTH WEST AFRICA.......... 42
  A. ZULULAND.......... 42
  B. NORTH-WEST CAPE PROVINCE.......... 46
    1. Kaigas, Richtersveld, Namaqualand district.......... 46
    2. Onseepkans, Kenhardt district.......... 46
    3. Styerkraal, Kenhardt district.......... 47
    4. Dyasonsklip, Gordonia district.......... 47
  C. SOUTH WEST AFRICA.......... 48
    1. Garub 83, Keetmanshoop district.......... 48
    2. Aukam 104, Bethanie district.......... 51
    3. Marburg 1, Otjiwarongo district.......... 52
    4. Karibib area.......... 52
    5. Omaruru area.......... 53
    6. Warmbad area.......... 53

IV. RECOMMENDATIONS FOR FUTURE DEVELOPMENT IN THE UNION.......... 53

V. PREPARATION FOR MARKET.......... 54

VI. USES.. 55
  A. METALLURGICAL INDUSTRIES.. 55
  B. CHEMICAL INDUSTRIES... 56
  C. GLASS, ENAMEL AND CERAMIC INDUSTRIES.............................. 57
  D. CEMENT INDUSTRIES... 58
  E. MISCELLANEOUS MINOR USES.. 58
  F. A NOTE ON OPTICAL FLUORITE.. 59
VII. GRADING... 60
VIII. SPECIFICATIONS... 61
  A. METALLURGICAL INDUSTRIES.. 61
  B. CHEMICAL INDUSTRIES... 62
  C. GLASS, ENAMEL AND CERAMIC INDUSTRIES.............................. 62
IX. WORLD PRODUCTION... 63
X. SOUTH AFRICAN PRODUCTION.. 63
  A. TRANSVAAL... 63
  B. NATAL... 65
  C. SOUTH WEST AFRICA... 65
  D. TOTAL PRODUCTION IN THE UNION AND SOUTH WEST AFRICA............... 65
XI. THE SOUTH AFRICAN EXPORT TRADE IN FLUORSPAR........ 65
XII. SUPPLIERS OF FLUORSPAR IN SOUTH AFRICA................ 68
XIII. PRINCIPAL PURCHASERS OF FLUORSPAR IN SOUTH AFRICA 68
XIV. RULING PRICES.. 68
XV. SELECTED REFERENCES... 68

LIST OF ILLUSTRATIONS

I.—PLATES FACING PAGE

PLATE I.—The Geology of Portion of the Marico district—Western Transvaal.. 10
PLATE II.—Gilspar Fluorite mine, Ruigtepoort 1373 (Goudkoppies)—Waterberg 28 district.. 32
PLATE III.—Fluorspar occurrences on Vischgat 1091 and Buffelsfontein 969..

II.—TEXT FIGURES PAGE

FIG. 1.—Fluorite workings on Cyferfontein 1094—Waterberg district........ 21
FIG. 2.—Fluorite occurrence on Tooyskraal 282—Waterberg district (Small scale general map)... 23
FIG. 3.—Fluorite occurrence on Tooyskraal 282—Waterberg district (Large scale plan).. 25
FIG. 4.—Sketch map showing Fluorspar occurrences on Ruigtepoort 1373 and Slipfontein 528.. 27
FIG. 5.—Big Ben Fluorite mine, Slipfontein 528—Rustenburg district........ 29
FIG. 6.—Fluorite occurrence on Vischgat 1091—Waterberg district.......... 31
FIG. 7.—Fluorite occurrence on Buffelsfontein 969—Potgietersrust district.... 33
FIG. 8.—Fluorite occurrence on Grobbelaars Hoek 785—Potgietersrust district 35
FIG. 9.—Fluorspar occurrence on Roodeplaat 314—Pretoria district........ 38
FIG. 10.—Sketch map showing Fluorspar veins near Hlabisa, Zululand...... 43
FIG. 11.—Diagrammatic section of the Garub Fluorspar body—South West Africa.. 50
FIG. 12.—Fluorspar production and exports, 1923–1939.................... 66

ABSTRACT

This bulletin records the results of the investigations of the known deposits in the Union of South Africa and South West Africa.

In the Transvaal, where the major deposits are found, fluorspar occurs in the Dolomite series, the Rooiberg felsites, the Red granite, and the alkaline rocks. Of these deposits only those in the Dolomite and Red granite have been found to be of sufficient purity and extent to be exploitable. In former years the bulk of the production came from replacement deposits in the dolomite of the Marico district; the present supplies, however, are largely obtained from veins and pipe-like bodies in the Red granite.

A vein of high grade fluorspar in Old gneiss has recently been found by the Geological Survey in the Gordonia district of the Cape Province. The occurrence is considered to be of economic interest.

Two of the three deposits that have been worked in South West Africa also occur in granite. The other, which is in metamorphosed sediments near Otjiwarongo, contains several million tons of low grade fluorspar.

The reserves of the Union of South Africa are estimated to be of the order of three-quarters of a million tons. In view of the rapidly increasing demand by metallurgical industries, a policy of conservation of resources in conjunction with more efficient and economical exploitation is recommended.

An account is given of the properties, mode of occurrence and uses. Specifications drawn up by local consumers are also included.

I. INTRODUCTION

Fluorspar has become of increasing importance in South Africa of recent years, owing to the establishment and rapid growth of the local steel industry, in which the mineral is extensively used. A substantial export trade was also built up, but this has declined considerably since the present war began.

It is an essential mineral for the metallurgical and chemical industries, and it is therefore desirable to assess as far as possible the available supplies.

A. NOMENCLATURE

Fluorspar is the common and commercial name of the mineral fluorite or fluor, which is the fluoride of calcium, CaF_2 (Ca 51·1 per cent., F 48·9 per cent.). The industrial importance lies in its being the only common and widely distributed mineral containing the important element fluorine in large amounts.

In Great Britain fluorspar is often referred to as Derbyshire spar or Durham spar. A banded fibrous columnar variety, formerly mined at Castleton, in Derbyshire, and used since the time of the Romans for making ornaments, is widely known under the name of "Derbyshire Blue John".

Green fluorspar from South West Africa has been sold under the name of "African emerald", while other coloured varieties are known in the jewellery trade as "false emerald" and "false amethyst".

Miners and those employed in the metallurgical and chemical industries often refer to fluorspar as the "spar". This practice, however, is confusing as other lustrous and cleavable minerals such as Iceland spar or calc-spar (calcite), heavy spar (barite), and felspar are also known as "spars".

B. PROPERTIES

The mineral crystallises in the isometric system, the most common forms being cubes, and cubes modified by hexakisoctahedra, octahedra, tetrahexahedra and less commonly dodecahedra.

A vicinal form produces striations on cube faces. Pseudo-octahedra made up of minute cubes grown in parallel positions are often encountered in fluorspar deposits. Twin crystals, and particularly inter-penetration twins [twin plane (111)] are common.

Some crystals are cylindrically rounded on the triakisoctahedron zone owing to the development of convex faces.*

An important and characteristic feature of fluorspar crystals is their perfect octahedral cleavage. This property renders fluorspar easily distinguishable from other similar glassy minerals such as calcite, barite, and quartz with which it is commonly associated, because crystalline fluorspar, even if well-formed crystals are not seen, generally shows cleavage cracks intersecting in equilateral triangles. For the same reason most of the small broken fragments have triangular outlines.

The fracture varies from flat-conchoidal to splintery in exceptionally compact varieties, such as those occurring at Buffelshoek 284 in the Marico district. The mineral is very brittle. When struck or pulverised certain purple varieties emit a peculiar pungent fetid odour, which is said to be due to the presence of occluded free fluorine. In South Africa the purple fluorspar from the Pilansberg exhibits this property, but the odour is perhaps to be attributed to the presence of sulphide inclusions.

The hardness is 4 (*cf.* calcite 3, quartz 7) and it can be readily scratched with a knife. The specific gravity ranges from 3·01 to 3·25, being 3·18 in the case of pure crystals. A cubic foot of the massive mineral thus weighs about 190 to 200 lbs. (*cf.* calcite 170 lbs./cubic ft.).

Fluorspar exhibits as wide a range of colours as any other mineral. Various shades and intensities of violet, deep purple, blue, green, yellow, orange, pink, red, grey, brown, and black are known. It may be colourless, but commonly is mottled or multi-coloured. Microscopic examination shows that the colour is generally not uniformly distributed. Many apparently deeply coloured crystals are only slightly coloured or colourless in their interiors.

Coloured varieties often lose their colour when heated to 200°–300° C. or when exposed to sunlight for a lengthy period. Fluorspar which has been decolorised by heating may be recoloured by exposure to radium or cathode rays. The restored colour, however, is not necessarily the same as the original one and in fact is generally bluish or lilac, irrespective of the original hue.

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* BROOMÉ, B.—"Über Kristalle von Flusspat mit krummen Flächen." *Geol. Fören. Stockh. Förh.*, 42, *Hf.* 6, 1920, *pp.* 368–377.

The nature of the pigments is not known. Some coloured varieties give off hydrocarbon gases on heating, and as the residuum is left colourless, the colour has often been attributed to the presence of hydrocarbon compounds. Other workers, however, have suggested that compounds of iron or manganese, or colloidal compounds of calcium and allied elements, or even radioactivity, may be the colouring agents.

In large deposits white, grey, yellowish, or brownish fluorspar is generally the most frequent, while in narrower veins and when well-crystallised it is commonly green or purple. The other coloured varieties are rather rare. The relationship between colour and type of occurrence, as illustrated by South African deposits, will be discussed in a later section.

The streak is white, save in all purple varieties when it is pinkish or pale lavender.

Fluorspar varies from perfectly transparent to subtranslucent. The lustre is generally glassy, especially on cleaved surfaces, but the natural crystal faces are usually dull and may exhibit many tiny etch pits. Granular varieties have an earthy lustre. A sub-metallic lustre is rare.

Fluorspar has a low index of refraction ($n = 1{\cdot}4339$) and a low dispersion ($0{\cdot}00454$ for C–F interval). It is generally isotropic but certain specimens locally strained show anomalous double refraction. Most clear crystals are transparent to both the ultra-violet and infra-red parts of the spectrum but are only slightly transparent to X-rays.

Some deeply-coloured crystals possess the remarkable property of showing one colour by transmitted light and another by reflected light. Such crystals are generally green by transmitted light and blue or purple by reflected light. This phenomenon, which was first recognised in fluorspar, is known as *fluorescence.* Another type of fluorescence, which is commonly exhibited by fluorspar, can be seen in the dark when atoms in the mineral are stimulated by various forms of energy such as heat, ultra-violet rays of certain wave-lengths, cathode rays, X-rays, and radium rays. When the exciting source is removed some specimens continue to glow; this property is termed *phosphorescence.*

Some fluorspars after excitation phosphoresce wholly or mainly in the ultra-violet and not in the visible spectrum; such phosphorescence may be detected by placing the specimens in contact with a photographic plate.

Brown* found that after insolation the purple and blue-green varieties phosphoresce strongly, the light green variety faintly, and the colourless and some light blue varieties not at all. He also noted that after bleaching by sunlight the phosphorescence induced by insolation is very faint as compared with that of the original coloured fluorspar.

A wide range of wave-lengths excite phosphorescence in fluorspar and it has been observed* that the longer wave-lengths bring phosphorescence to a maximum value much faster than the shorter ones.

---

* Brown, W. L.—"Photo-Phosphorescence in Minerals." *Univ. Toronto Stud. (Engng.) geol.,* 35, 1933, *pp.* 19–35.

Fluorspar frequently exhibits phosphorescence when heated to a temperature below red heat (about 150° C.) preferably in a closed tube, because it decrepitates. As it phosphoresces into the infra-red this *thermoluminescence* is probably a continuous phenomenon with ultra-violet and visual phosphorescence.

In fluorspar the thermoluminescent colour may change several times during the heating process.

An yttrium-bearing chlorophane variety of fluorspar from Amelia County, Virginia, is rendered distinctly luminous by the warmth of the hand. Preliminary exposure to radium rays[*] may result in thermoluminescence at temperatures as low as 50° C. After treatment with radium rays many specimens of colourless fluorspar exhibit thermoluminescence although previous to this they did not, even when heated to 240° C.[*]

Wick's[†] spectroscopic investigations have shown that many fluorspars contain rare earth elements and she has suggested that the luminescence may be due to the presence of atoms of these elements in the crystal lattice. It was noteworthy that after exposure to radium rays the rare earth bands in the spectra were intensified.

Some specimens of the chlorophane variety may even phosphoresce after they have been scratched, while many others exhibit this *triboluminescence* if they are pulverised. Nevertheless, Wick[†] has shown that after subjection to great pressure (*e.g.*, 10,000 kg/cm^2) the thermoluminescence of fluorspar is very much less intense.

Deep purple fluorspar from an uraninite-bearing pegmatite in Ontario is in patches almost as radioactive as pitchblende. This fluorspar does not contain inclusions of radioactive minerals and Hess[‡] suggested that RaF_2 may have crystallised isomorphously with the CaF_2, giving a mineral for which he proposed the name " radio-fluorite ".

When heated fluorspar generally decrepitates or flies apart, sometimes with explosive violence. Certain massive non-cleavable varieties, *e.g.* the massive fluorspar from Buffelshoek 284, Marico district, can be heated to high temperatures without cracking. It melts between 1,270° C. and 1,387° C. to a very mobile liquid.

Fluorspar fluxes or forms eutectics with silica, alumina, calcium and barium sulphates, and other refractory materials to give easily fusible and very fluid slags, and is therefore of great value in the metallurgical industries.

When treated with warm sulphuric or nitric acids, or gaseous hydrogen chloride, the mineral decomposes, giving off fumes of hydrogen fluoride :—$CaF_2\ H_2SO_4 \rightarrow CaSO_4 + 2HF\uparrow$.

If silica is present and an excess of sulphuric acid is used, hydrofluosilicic acid (H_2SiF_6) is formed. Decomposition of fluorspar may also be brought about by heating in a current of steam.

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[*] Doelter, C.—" Über Thermoluminescenz bei Flusspat." *Zbl. Min. Geol. Paläont.*, 1924, *pp.* 419–421.

[†] Wick, F. G.—" A Spectroscopic study of the Cathodo-luminescence of Fluorite." *Phys. Rev.*, 24, 1924, *pp.* 272–282.
" Thermoluminescence excited by exposure to Radium." *J. opt. Soc. Amer.*, 21, 1931, *pp.* 223–231.

[‡] Hess, F. L.—" Radioactive Fluorspar from Wilberforce, Ontario." *Amer. J. Sci. Ser.* 5, 22, 1931, *pp.* 215–221.

Fluorspar crystals can be etched by prolonged immersion in even cold dilute acids, sodium carbonate solution, etc. Both natural and artificial etch pits are square in shape and oriented at 45° to the edges of the cube.

The mineral is slightly soluble in natural waters containing carbonates and bicarbonates, and thermal alkaline springs are generally rich in soluble fluorides. Fluorine in domestic water supplies is dangerous, for if present in amounts greater than one part per million it may cause fluorosis of the teeth* and bones. It is therefore desirable that the drinking water obtained near fluorspar mines or deposits be tested† for fluorine.

Solution by natural waters has in many cases resulted in the preservation of casts (epimorphs) of fluorspar in associated stable minerals such as quartz and chalcedony.

Fluorspar can take into crystal solution up to 50 per cent. YF_3 and the mix-crystals are called *yttrofluorite*. If cerium is also present in notable amount the mineral is termed *yttrocerite*. This latter very rare mineral has been found in the Potgietersrust tinfields.‡

C. STRUCTURE

Well-formed crystals are usually found only in druses and vughs, along the sides of underground water-courses in limestones, or less commonly embedded in residual clays. Small crystals occur as inclusions in magnetite and other minerals.

Fluorspar, however, occurs not only as crystals but also as crystalline aggregates, and in columnar, fibrous, spheroidal and massive forms. It has been suggested** that a spheroidal variety is of colloidal origin.

Beautiful stalactites made up of crystals of purple fluorspar and quartz were formerly obtained at Boltsburn, England.

Nodular fluorspar was collected by the writer at the Cyferfontein mine near Warmbaths.

In some deposits, as at Madoc, in Ontario, the mineral exhibits a porous cavernous structure. At other localities, for example Cave in Rock, Illinois, where a bedded and false-bedded limestone has been replaced, horizontal layers of high-grade fluorspar are " bedded ".

Massive fluorspar may be either granular like a friable sandstone (*e.g.*, No. 2 quarry, Witkop, Marico district) or extremely fine-grained like a marble (*e.g.*, Wagon Wheel Gap, Colorado).

Some veins of fluorspar are crustified, either finely or coarsely, in shades of one colour or in many and often contrasting colours. The individual bands may range in thickness from mere partings up to a foot or more. The banding is generally simple and symmetrical, indicating deposition in open channel-ways; but early fluorspar may be brecciated and veined and replaced by younger. In addition to crustification in veins of more or less pure fluorspar, the bands may be associated in veins with bands of such minerals as calcite, barite, galena, quartz and chalcedony.

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* OCKERSE, T., and MEYER, H. P.—" Endemic Fluorosis in the Pilansberg Area and the Occurrence of Fluorine in the Saltpan, Pretoria District." *S. Afr. dent. J.*, 15, 1941, *pp.* 62–72.

† For details of a simple colorimetric method see *Industr. Engng. Chem. Anal. Ed.* 6, 1934, *p.* 134.

‡ PARTRIDGE, F. C.—" A Contribution to the Mineralogy of the Potgietersrust Tinfields." *Trans. geol. Soc. S. Afr., XXXIX*, 1936, *p.* 462.

** STOICOVICI, E., and GLISZCZYNSKI, S. V.—" Über sphäroidischen Flusspat von Ivigtut." *Zbl. Min. Geol. Paläont. Abt. A.*, 4, 1938, *pp.* 113–115.

D. TYPES OF OCCURRENCE

Fluorspar is a very widespread and persistent mineral and can form over a very wide range of environmental conditions.

It occurs as a minor accessory in certain granites and granite pegmatites—a South African example being the Red granite of the Bushveld. Fluorspar is a common accessory in alkaline rocks, especially in holocrystalline types such as syenites and nepheline syenites. Deposits of notable size occur associated with alkaline rocks, as in the Pilansberg.

The workable deposits are generally veins or replacements of the lower temperature range leptothermal or telethermal types.

Veins consisting wholly or partly of fluorspar occur in both acid and basic igneous rocks, in gneisses and schists, and in sedimentary rocks, especially calcareous ones. They are generally located in true fissures, such as faults or shear planes, and are not as a rule genetically connected with the wall rocks. The veins themselves are either true fissure-fillings or replacements along less-open dislocations, or combinations of both types.

These veins may consist wholly of fluorspar, or of this as a gangue associated with lead, silver, gold, zinc, tungsten and tin minerals, barite, calcite, quartz, chalcedony etc. For example, the deposits along the Rosiclare fault in Illinois are of the fissure-vein type.

Replacement deposits are generally confined to limestones or dolomites and the fluorspar may be more or less pure, or associated with such ores as galena and sphalerite. The well-known Derbyshire deposits, for example, occur with galena, barite and calcite in the upper part of the Carboniferous limestone. The Derbyshire occurrences are differentiated into *rake veins*, which are deposits in enlarged joints, faults or fissures, *pockets*, *pipes* and *flats*. The " flats " are lenticular or tabular bodies which lie practically horizontal and usually develop under impervious beds. " Flats " also occur in the Marico district and prospectors who have mistaken them for the tops of pipes have been greatly disappointed.

Fluorspar is found sparingly in pyrometasomatic deposits. One such deposit of some economic importance occurs at Mount Realejo, Mexico, and the gangue is garnet, calcite, pyrite and tourmaline.

Crystals of fluorspar have also been found in recent alkaline lava flows and around fumaroles on Vesuvius.

Some thermal spring sinters and tufas contain fluorspar in association with such minerals as aragonite, calcite, barite and silica *e.g.*, the Carlsbad and Plombierés springs. The fluorspar in such thermal spring deposists is generally amorphous. A large vein deposit of fluorspar sinter at Wagon Wheel Gap, Colorado, yielded 110,000 tons up to 1936.

Fluorspar occurs both as a detrital and as an authigenic mineral in some recent sediments and sedimentary rocks. It has even been found in the interiors of fossils.

As the mineral is fairly resistant to weathering, eluvial "gravel spar" is of common occurrence.

From the geochemical point of view deposits may form in a number of ways :—

(1) Ground-water circulation may concentrate fluorspar from adjacent rocks if they contain the necessary calcium and fluorine.

(2) The calcium may be derived from the surrounding or underlying rocks while the fluorine is of magmatic origin.

(3) Both the calcium and the fluorine, and the solutions or vapours from which the fluorspar was deposited, may be of magmatic origin.

E. The Relationship of the Colour of Fluorspar to the type of Occurrence

The conditions of formation appear to have a notable effect on the colour. In the northern Pennine area, England, Dunham* observed that where the fluorspar is associated with barite it is amber coloured in contradistinction to barite-free fluorspar, which is mauve or green. In Derbyshire, however, green and purple varieties are associated with barite, and Dunham concluded that these crystallised at a higher temperature than the amber. In the Cyferfontein deposit near Warmbaths, Transvaal, the writer observed that the first formed fluorspar is colourless and transparent. It occurs as irregular fragments up to a centimeter or so in diameter in a fine, granular, white fluorspar, which is probably a recemented gouge. Both these types are cut by veins of maize-coloured columnar fluorspar up to 8 cm. in thickness, which sometimes contain thin brownish purple bands. Further movements along the vein caused this younger columnar fluorspar to be locally shattered and brecciated and it is veined and cemented by still younger, very pale greenish-white granular fluorspar. Finally, bands of a pale purple colour up to 2 mm. in thickness cut across the earlier primary banding at small angles.

It cannot be stated with any certainty that the older fluorspar was deposited in the Cyferfontein veins at a lower temperature than the younger.

Wilson (11, *p.* 2) also noted that "most of the fluorspar in pegmatites and other deposits of the high temperature class is purple or violet, whereas the more delicate hues such as honey-yellow, pale green and rose prevail in the deposits of the low temperature type".

In Illinois there appears to be a relationship between the colour of the fluorspar and the nature of the country rock housing the veins. In general, fluorspar in contact with shale walls is of a bluish hue, while veins in contact with limestone walls are white or cream coloured. (6, *p.* 20.)

In South Africa similar interesting relationships exist :—

1. REPLACEMENT DEPOSITS IN THE DOLOMITE, MARICO DISTRICT

The fluorspar from the deposit on Oog van Malmanie 101 is generally colourless or pale blue, bluish green, or yellowish green.

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* Dunham, K. C.—"The Paragenesis and Color of Fluorite in the English Pennines." *Amer. Min.*, 22, 1937, *pp.* 468–477.

Occasional patches are white and cloudy, grey, or brownish claret. A deep purple variety* was found near the contact of the ore body and the dolomite country rock. (cf. Karibib area *p.* 53.)

The deposits on Witkop 288 and Stinkhoutboom 96 contain white, colourless, and grey and colourless types respectively. On Buffelshoek 284 the fluorspar is colourless or less frequently grey or pale green. No violet or claret-coloured variety was found. (Kupferbürger, *op. cit.*, *p.* 34.) At the Doornhoek 32 lead mine the fluorspar is colourless or very pale mauve.

It is interesting to note that Oog van Malmanie 101 lies farthest from the contact of the Dolomite and the Pretoria series, while Buffelshoek 284 and Doornhoek 32 are situated relatively near to this contact. Witkop 288 and Stinkhoutboom 96 occupy intermediate positions. (Plate I).

A little sphalerite is sometimes found associated with the fluorspar at Oog van Malmanie, while at Doornhoek galena is abundant. At Witkop and Buffelshoek, on the other hand, sphalerite is plentiful, while the dolomite country rock at Witkop contains much tremolite. Thus there is evidence for some paragenetic zoning which may explain the colour differences between the various deposits.

In general the fluorspar in the Dolomite is characterised by its transparency and slight degree of coloration.

2. DEPOSITS IN THE RED GRANITE OF THE BUSHVELD IGNEOUS COMPLEX

The fluorspar at Tooyskraal 282, Slipfontein 528, Vischgat 1091, and Ruigtepoort 1373 is colourless and cloudy or white, while that from the now worked-out occurrence on Grobbelaars Hoek 785 is colourless, pale blue and pale greyish green. Buffelsfontein 969 has a pale green variety.

The Cyferfontein 1094 fluorspar is maize-coloured, colourless, white, greenish-white and, less commonly, brownish-purple and mauve. (*See p.* 9.)

In general the fluorspar in the Red granite is characterised by relative opacity and absence of colour.

3. DEPOSITS IN ALKALINE ROCKS

In the Pilansberg and Leeuwfontein alkaline complexes the fluorspar, which is associated with apatite, is a deep purple. A few relatively thin veins of pure fluorspar in the Pilansberg, however, are colourless.

4. OCCURRENCES ASSOCIATED WITH TIN DEPOSITS NEAR POTGIETERSRUST

Fluorspar is a common gangue mineral in the tin deposits in the Red granite and granophyre but does not occur in those in quartzite. " The mineral displays a wide range of colour, including pale pink, yellow, brown, pale green, bright apple-green, violet, dark violet, purple and deep bluish-purple. Clear colourless crystals are also met with in some of the occurrences in granophyre."†

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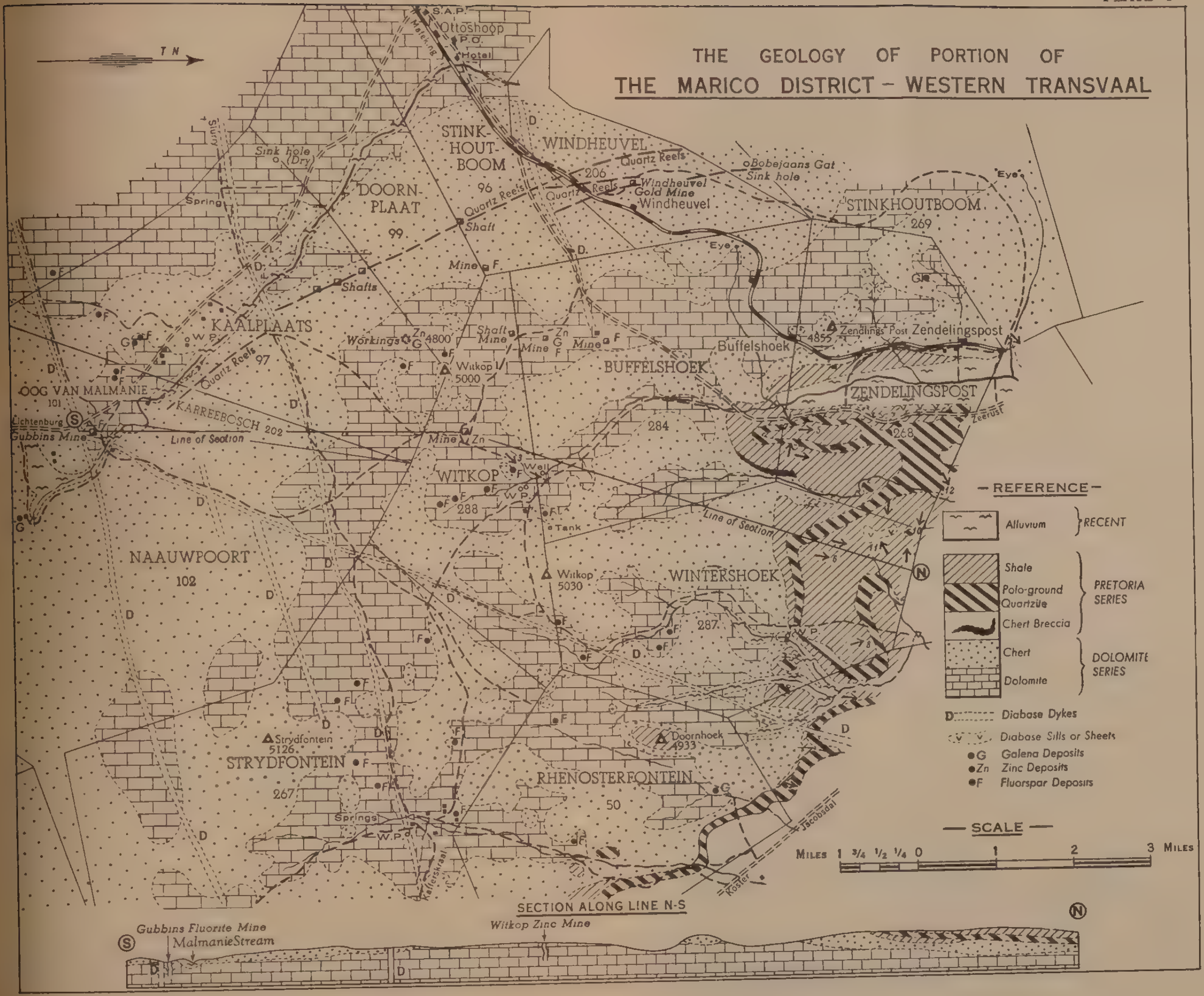
* KUPFERBÜRGER, W.—" The Fluorspar, Lead and Zinc Deposits of the Western Transvaal." *Trans. geol. Soc. S. Afr., XXX*, 1927, *p.* 29.

† WAGNER, P. A.—" The Mutue Fides-Stavoren Tinfields." *Mem.* 16, *Geol. Surv. S. Afr.*, 1921, *p.* 73.

PLATE I



THE GEOLOGY OF PORTION OF THE MARICO DISTRICT – WESTERN TRANSVAAL

In general the fluorspar in the tin mines is of the transparent fairly strongly coloured type.

5. MISCELLANEOUS OCCURRENCES

The fluorspar in a pegmatite at Onseepkans, 100 miles west of Kakamas, is purple and greenish white. That which occurs in association with monazite at Houtenbek 392, seventy-five miles north-east of Pretoria, is a deep bluish-violet.* The deposit occurs in a fissure in the Red granite.

A vein on Valschfontein 432, Pretoria district, contains dull blue-green fluorspar and barite.

A fluorspar vein in Dwyka tillite one mile north-east of Hlabisa, Zululand, is pale mauve with green margins. A finely-banded purple vein is found in Old granite at Rabe's claims nearby.†

Colour zoning in a pipe-like body on the farm Garub, Karasburg, S.W.A., is described on p. 49 (L. E. K.)

II. OCCURRENCES IN THE TRANSVAAL

A. Occurrences in Dolomite

1. INTRODUCTION

Between 1917 and 1936 the western Transvaal was the major producer of fluorspar in South Africa. The principal deposits are situated in the south-western part of the Marico district to the east of the village of Ottoshoop.

The Mafeking–Johannesburg railway line passes through the area and the main roads from Ottoshoop to Zeerust and Lichtenburg run along the western and southern limits of the fluorspar field respectively.

The presence of fluorspar in the area was known long before active exploitation of the deposits commenced in 1917. The mining of the mineral was due, no doubt, to the establishment of a market for high grade fluorspar in the U.S.A. Only ore of not less than 98 per cent. purity was exported, and this came chiefly from the deposits on Oog van Malmanie 101, Witkop 288, and Buffelshoek 284.

Since 1936 the amount of fluorspar produced in the western Transvaal has been very limited, as mining operations were suspended on the farms mentioned above, and only small quantities have been produced from scattered occurrences of minor importance.

The fluorspar occurs both in dolomite and in chert of the uppermost part of the Dolomite series as replacements of varying magnitudes. (Plate I.)

2. OOG VAN MALMANIE 101

(*a*) *Locality*.—The fluorspar occurrence which was worked by the late Dr. J. J. Gubbins is situated about a quarter of a mile east of the Ottoshoop–Lichtenburg main road and is approximately 1 mile north-west of the Malmanie "Eye". The workings are about 9 miles from Ottoshoop railway station.

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* Wagner, P. A.—"Fluorspar." *S. Afr. J. Industr.*, 1, 16, 1918, *p.* 1520.

† Kuperbürger, W.—"Fluorspar veins near Hlabisa, Zululand." *Trans. geol. Soc. S. Afr., XXXVII*, 1934, *p.* 93.

(*b*) *History.*—From 1917 to 1926 this deposit provided about 30,000 tons of high-grade spar most of which was exported to the U.S.A. Since then production has been on a smaller scale.

At the beginning of 1940, a small syndicate under the direction of Mr. L. R. Heilmann was busy cleaning out this quarry by means of two power cranes operating from the surface.

(*c*) *Water.*—At a depth of 85 feet a pump had to be installed to deal with the inrush of water. With increase in depth serious difficulties may be experienced on account of underground channels which are probably fed by water from the Malmanie stream, 250 yards to the east of the workings.

(*d*) *The Deposit.*—The partially depleted deposit known locally as Gubbins' mine consists of a huge mass of practically pure fluorspar occurring in the uppermost beds of the Dolomite series.

As a rule the contact between the fluorspar and the country rock is well-defined, with a thin selvedge of talcose material commonly occurring at the junction.

The fluorspar lies in massive dolomite overlain by chert, which probably acted as a barrier to the mineralising solutions that have completely replaced the dolomite along vertical joint planes trending east-west.

On the surface the country rock surrounding the deposit is remarkably free from veins or irregular replacements by fluorspar. This suggests that the lateral boundaries will continue to be well-defined with increase in depth. Occasionally small stringers of fluorspar are found in the dolomite and chert, but these are very small and do not continue far from the main body.

The shape of the body is irregular and the part worked out resembled a boot, with the toe pointing east. The original outcrop, according to Kupferbürger,* was roughly circular with a diameter of about 10 feet. With increase in depth the body increased in size, bulging particularly to the east and the west. At the bottom of the quarry the diameters are roughly 80 feet east-west and 40 feet north-south.

The floor of the quarry is almost wholly covered by waste material fallen from the walls. At the eastern end, where the floor has been exposed, pale green fluorspar covers an area 15 feet by 6 feet.

On the western wall a fluorspar body about 6 feet wide was being followed up, but is probably only an offshoot and is not expected to continue very far westwards.

Whether or not the pipe persists to greater depths it is impossible to state. It is probable, however, that it will continue as there is no evidence to suggest that the body has been exhausted.

(*e*) *Ores.*—The fluorspar is massive, crystalline, and transparent and exhibits well-developed octahedral cleavage. It ranges in colour from colourless to blue-green, whilst purple and wine-brown are sometimes seen. The fluorspar on the dumps, which have been exposed to the sun, is colourless.

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* KUPFERBÜRGER, W.—"The Fluorspar, Lead and Zinc Deposits of the Western Transvaal." *Trans. geol. Soc. S. Afr., XXX*, 1927, *pp.* 5–56

In the western part of the quarry sulphides are found as veins cutting through the fluorspar. The sulphides consist of pyrite, chalcopyrite and pyrrhotite. Kupferbürger* also reported the presence of galena and zincblende in small quantities, but none was seen by the writer.

Other Deposits.—Small deposits of fluorspar occur near the Malmanie " Eye " and near the fence between Oog van Malmanie 101, and Kaalplaats 97. The dumps from the latter deposit can be seen about a quarter of a mile south of the Ottoshoop-Lichtenburg road near the boundary fence.

The fluorspar at both these occurrences is present as irregular replacements and as a branching net-work of veins in dolomite, to the bedding and joint planes of which they have no relation. The ore bodies are too irregular and scattered to be of any economic importance.

3. BUFFELSHOEK 284

On this farm three separate deposits of fluorspar have been opened up, *viz.* : (i) The zincblende-fluorspar deposit, (ii) the " Gravel " deposit and (iii) Blane's No. 1 Quarry.

(i) THE ZINCBLENDE-FLUORSPAR DEPOSIT

(*a*) *Locality.*—This occurrence is about one mile N.E. of the S.W. beacon of Buffelshoek 284, approximately half a mile from the Ottoshoop-Zeerust main road, and about four miles by road from Ottoshoop station.

(*b*) *History.*—From 1908 to 1914 the deposit was prospected and partially developed as a source of zincblende, but no attempt has been made to work fluorspar.

(*c*) *The Deposit.*—At the surface, fluorspar associated with a little zincblende and galena is found as a branching network of gash veins, individually up to two or three feet thick, in massive slightly altered dolomite. The mineralised zone covers a circular area approximately 300 feet across.

There is no evidence of a barrier extending over the deposit at this locality, but it is likely that the chert horizon, since removed by erosion, formed a barrier to the mineralising solutions.

The fluorspar is massive, colourless, and of good quality and it is possible that some type of concentrating plant could separate it from the sulphides.

From the mine plans of the prospecting carried out for zinc ores, it appears that the zone of mineralisation is pipe-like in shape.

The fluorspar outcrops comprise about 7 per cent. of the mineralised area and, assuming that the deposit persists uniformly to a depth of 80 feet, the ore reserves are estimated to be 37,000 tons.

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* Kupferbürger, W.—*op. cit.*, *p.* 29.

(ii) THE "GRAVEL" DEPOSIT (NO. 3 QUARRY)

(*a*) *Locality.*—This deposit lies a quarter of a mile west of the south-east beacon of Buffelshoek 284, and is approximately 9 miles by road from Ottoshoop Station.

(*b*) *History.**—The interbedded granular spar occurrence on the farm was discovered in 1930 by Mr. F. T. Blane, of Western Quarries, Ltd.

Bulk samples of the ore were submitted to Messrs. Minerals Separation, Ltd., of 62 London Wall, London, for dressing tests, and in 1936 a flotation plant was erected on the property at a cost of £14,000. An output of 500 tons of ground spar containing 98 per cent. CaF_2 and less than 1 per cent. each of silica and lime was intended, but the plant was a complete failure and was eventually dismantled and sold.

(*c*) *The Deposit.*—Here the mode of occurrence differs from that of the other deposits in the Marico district.

Apparently the fluorspar partially replaced the dolomite, underlying the chert of the uppermost part of the Dolomite series, along bedding planes. Subsequently the unreplaced dolomite was leached out leaving residual manganese earth ; the consequent diminution of volume caused the fluorspar seams to break up into angular grains and to become intermixed with a little manganese earth. The resultant deposit thus has a remarkable bedded nature, consisting of thin alternating layers of granular fluorspar and manganese earth.

The limits of the deposit are not known but it probably occurs both on Buffelshoek 284 and Witkop 288. All but two of the prospecting pits have been filled in or have slumped in. These two pits are 200 yards and 50 yards north of the southern boundary fence of Buffelshoek 284.

The deposit is well-exposed in the northern pit, which is 30 feet long, 20 feet wide and 20 feet deep and is accessible from the southern side. There is a 3–6 feet overburden of soil and chert rubble and the deposit is at least 13 feet thick and contains 50–60 per cent. fluorspar. The total thickness was not penetrated and may be much greater than 13 feet.

The southern pit is situated near the outer limits of the deposit, and here the effects of recent erosion may be seen.

Mr. Cowper, of Oog van Malmanie 101, reports that in August, 1939, on a trial run he was able to concentrate the material to 95 per cent. fluorspar. The plant employed was of the type commonly used on the alluvial diamond fields for washing gravels. It included 3 power-driven pans, two with diameters of 6 feet and one 12-foot in diameter. Although the production stage was reached no fluorspar was produced owing to the outbreak of war.

(*d*) *Water.*—Water is obtainable from a well in alluvium in the valley about 1,000 yards west of the occurrence. This should prove a reliable source as two windmills a few hundred yards south of this well deliver a good supply.

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* Information from Deputy-Inspector of Mines, Johannesburg.

(*e*) *The Dressing of this Ore**—

(i) *Screening, Dry tabling, and Magnetting.*—A preliminary separation is effected by screening, and sizes below a certain limit containing too little spar to justify treatment, or because treatment is uneconomically laborious, are rejected. The remaining material is divided into suitable size-groups and discrete silica, composite particles of low specific gravity, mica and some other light or tabular particles are removed by dry tabling each fraction separately. The undesirable and removable constituents now remaining consist of concretions of limonitic wad and some fluorspar adhering to, or encased in, such concretions. Their removal may be effected by treatment on any medium-intensity magnetic separator. If desired, adhering dust may be washed off.

The accompanying table illustrates how markedly the spar is concentrated in the coarser fractions.

GRADING AND ASSAYS BUFFELSHOEK FLUORSPAR EARTH

Screen B.S.	Per cent. Weight on Screen.	Percentage CaF_2.	Cumulative Percentage of Total CaF_2 in Oversize.
+ 7	5·3	83·0	6·2
− 7 + 14	27·8	90·3	41·8
− 14 + 25	23·6	91·1	72·3
− 25 + 52	13·6	83·0	88·5
− 52 +100	9·0	35·0	92·9
−100 +200	5·5	25·2	94·3
−200	15·2	3·0	100·0

Tests on a 200 ℔. sample showed that a product containing more than 98 per cent. CaF_2 can be made without washing, and that one containing 97 per cent. CaF_2 can be prepared by admixture of second concentrates and middlings, giving an over-all extraction of 75 per cent. of the spar in the feed. The principal sources of loss are in spar associated with limonitic wad and in the −60-mesh fraction.

(To confirm the laboratory tests 10 tons of the crude gravel as mined, which contains about 70 per cent. CaF_2, was treated in a commercial Kipp-Kelly plant. A general sample of the concentrate leaving the table was found to contain 95 per cent. CaF_2, while after passing the magnetic separator the grade rose to 97 per cent. CaF_2.)

The chief advantages of this process would be :—

(1) The plant is simple, easily installed, manipulated and maintained, and is reasonably cheap.

(2) No water is required except for washing, which is not wholly necessary.

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* Extracts from an unpublished report, "The Dressing of Marico (Buffelshoek) Fluorspar Earth," by J. E. Laschinger of the Minerals Research Laboratory, University of the Witwatersrand.

(3) Very little crushing is required, and the material is recovered at or very near the coarsest possible condition.
(4) The plant may be worked discontinuously without disadvantage.

The disadvantages of the process would be :—

(1) The treatment of the finest fractions is laborious and expensive, so that recovery of sizes below about 60 mesh is probably uneconomical.
(2) The material must be bone-dry.
(3) Considerable, possibly injurious, dust may attend the working of the plant.

On a commercial scale dry screening might be modified with advantage by preliminary hydraulic classification to remove −100 material, followed by draining, forced drying and dry screening, and dry screening to 30 mesh followed by air classification to remove the −60 fraction. Wet classification provides a satisfactory and effective means of dust-allaying and permits the fine tailings to be pumped to a dumping site and conveniently built up in the form of a slimes dam.

(ii) *Froth-flotation.*—Recovery of acid-grade spar from this material would involve a preliminary and very thorough washing to remove as much as possible of the fine ferruginous material ; a grinding to a suitable size for flotation, say all through 52 mesh, followed by flotation with oleic or some such fatty acid in the presence of slime dispersant, and finally settlement and drying of the concentrate. The advantages of such a process are :—

(1) The highest possible recovery.
(2) Comparatively low operating cost.
(3) Clean and healthy working.

On the other hand the disadvantages are :—

(1) Comparatively high initial cost of plant.
(2) The need for an abundant supply of good quality water.
(3) The need for skilled supervision.
(4) The production of a fairly finely-powdered product.
(5) The need for great care in maintaining uniform conditions making it most undesirable to work such a plant intermittently.
(6) The risk of losses consequent on faulty manipulation.

In view of these considerations and the failure of the earlier flotation plant, it is felt that the dry tabling method should be adopted.

(iii) BLANE'S NO. 1 QUARRY

(*a*) *Locality.*—The quarry, a quarter of a mile east of the late Mr. F. T. Blane's homestead, is five miles from the Ottoshoop railway station and is half a mile east of the main road to Zeerust.

(*b*) *History.*—This deposit was worked on a large scale by Western Quarries, Ltd., and yielded some thousands of tons of high-grade spar.

(*c*) *The Deposit.*—The workings consist of an open quarry roughly rectangular in shape, 100 feet long by 60 feet wide and about 80 feet deep. The quarry is unfortunately water-logged.

According to Kupferbürger* the deposit was similar to that on Oog van Malmanie 101. It consisted of a large mass of fluorspar in the dolomite, below the massive chert which outcrops to the east of the deposit.

East of the quarry shales are exposed at the base of a chert-capped koppie. This shale band undoubtedly served as a barrier to the mineralising solutions.

The country rock of the deposit is massive, slightly altered dolomite with fairly well-developed joint planes, in places running approximately N.-S. These joint planes appear to have controlled to some extent the replacement of dolomite by fluorspar. On the sides of the quarry the contact of the fluorspar and dolomite is in steps, with a selvedge of talcose material commonly occurring at the contact.

Pyrite and pyrrhotite occur both in the fluorspar and in the country rock. Kupferbürger* also reports the presence of marcasite, galena and zincblende; the galena being in the fluorspar, whilst the zincblende occurs in the country rock or in the fluorspar very near the contact.

If this deposit is to be worked at greater depths underground water may cause serious difficulties.

It is impossible to form an opinion of the ore reserves as the bottom of the quarry is water-logged.

4. WITKOP 288

(*a*) *Locality.*—The quarry on Witkop 288 is about 100 yards south of the northern boundary fence of the farm and approximately one mile north-west of the Witkop trigonometrical beacon.

(*b*) *History.*—The deposit was worked as No. 2 Quarry by Western Quarries, Ltd. from 1925 to 1936, but no production figures are available. It seems probable, however, that the amount was of the same order as that produced from Oog van Malmanie 101 and Buffelshoek 284.

(*c*) *The Deposit.*—The workings, which are water-logged, are about 150 feet in a north-south direction, 120 feet wide and about 60 feet deep. A vertical shaft on the western side of the quarry was used for haulage purposes, but the workings are now inaccessible.

According to Kupferbürger†, who visited the occurrence when it was still in the development stage :—" A crescentic mass of fluorspar of several thousand tons was exposed on the northern and western sides, and it appeared to dip away outwards underneath dolomite. Elsewhere in the quarry the fluorspar occurs in irregular branching veins up to three feet across, cutting shale and talcose dolomite. Four shafts have been sunk on the periphery of the quarry and one in the centre, and they reveal a zone of rather brecciated dolomite cut by veins of fluorspar surrounded by more or less normal dolomite.

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* KUPFERBÜRGER, W.—*op. cit.*, *p.* 33.

† KUPFERBÜRGER, W.—*op. cit.*, *p.* 35.

"Shale bands occur along the top of the quarry, and they are intercalated layers in the dolomite of the same horizon as those found near the No. 1 Quarry on Buffelshoek. In places the fluorspar is seen to cut across these shale layers, but otherwise the shales formed an unbroken cover over the deposit.

"Galena and a little zincblende is found generally near the outer limits of the deposit. The zincblende apparently replaces the galena. The galena carries silver to the extent of 4·32 ounces to the ton of 2,000 lb."

(*d*) *Other Deposits on Witkop* 288.—Fluorspar also occurs in the central and western parts of Witkop 288 as gash veins and irregular replacements in the dolomite underlying the massive chert. The occurrences are very scattered, however, and prospecting has not revealed any other large deposit.

On a small koppie about one mile north-east of the Witkop zinc mine, fluorspar occurs as a granular mass replacing chert parallel to its stratification. Unfortunately, a large percentage of this mass consists of residual chert and secondary quartz, which would make the concentration of the fluorspar difficult. This fluorspar, on breaking, gives off a strong distinct smell of sulphuretted hydrogen (H_2S). Dr. Wasserstein crushed some of this material, but failed to detect any sulphides after panning. A similar ore was found on the dumps from a prospecting shaft near the top of the chert-capped hill to the east of the Kaalplaats zinc occurrence.

5. STINKHOUTBOOM 96

(*a*) *Locality.*—On the farm Stinkhoutboom 96, near the S.E. beacon of the farm, and approximately four miles from Ottoshoop, is a quarry 40 feet square and 30 feet deep.

(*b*) *The Deposit.*—In 1940 the quarry was being cleaned out by Abdullah Sulliman. The fluorspar occurs as three apparently persistent bands replacing the massive chert along the bedding planes. The bands, which are about 6 to 10 feet apart, thicken and thin within the limits 3 to 12 inches and dip to the S.W. at 5°–8°. Unfortunately they are rather widely separated, and are not considered to be of any economic importance.

The bands do not outcrop and could be traced only in the workings.

The fluorspar is massive and colourless and exhibits the characteristic octahedral cleavage.

6. SMALL DEPOSITS IN THE MARICO DISTRICT

Fluorspar occurs as gash veins and irregular replacements of the dolomite underlying the massive chert of the Dolomite series, at a number of localities on the following farms :—

> Kaalplaats 97, Doornplaat 99, Naauwpoort 102, Strydfontein 267, Rhenosterfontein 50, Wintershoek 287, Doornhoek 32, Witrand 287, Knoflookfontein 150.

As the occurrences on these farms are of minor importance and only small amounts of fluorspar have been produced, it is not considered necessary to describe each separately.

Most of the work has been done by Abdullah Sulliman, and the annual production of each farm rarely exceeds 100 tons. Of the occurrences those on Strydfontein 267 and Wintershoek, 287 appear the most promising.

Unfortunately these deposits are not worked systematically. All the waste is dumped next to the workings, and it is thus impossible to give a fair estimate of ore reserves. The occurrences on Strydfontein 267 and Wintershoek 287 are probably of the same character as the zincblende-fluorspar deposit on Buffelshoek 284.

7. CONCLUSIONS

Of all the occurrences examined in the S.W. part of the Marico district the following are the most important :—

(*a*) *The "Gravel" Deposit on Buffelshoek* 284.—To enable an estimation of the ore reserves to be made it is suggested that pits be sunk at regular intervals, say 50 feet, so that the lateral and vertical dimensions of the deposit can be established. Although no accurate estimate of the ore reserve could be made it is considered to be of the order of one hundred thousand tons.

(*b*) *The Quarries on Buffelshoek* 284, *Witkop* 288 *and Oog van Malmanie* 101.—The most economical method of ascertaining whether these occurrences persist to greater depths would be to put down boreholes at the bottoms of the quarries.

(*c*) *The Zincblende-fluorspar Occurrence on Buffelshoek* 284.—The writer estimated the fluorspar reserves at about 37,000 tons. The deposit should be worked for the fluorspar content and the zincblende and galena recovered as by-products. Further prospecting on this deposit is not considered justifiable. (H.D.R.)

B. OCCURRENCES IN THE RED GRANITE OF THE BUSHVELD IGNEOUS COMPLEX

1. CYFERFONTEIN 1094, WATERBERG DISTRICT

(*a*) *Locality*.—The fluorspar mine is situated on portion D of the farm Cyferfontein 1094, Waterberg district. This farm is 3·7 miles by road from Mabula Post Office, which is 21 miles from Warmbaths along the Rooiberg road.

Cyferfontein 1094 is shown on Geological Survey Sheet 10 (Nylstroom) as 2124.

(*b*) *History*.—Fluorspar was first found on Cyferfontein 1094 by Mr. J. J. McCord, of Warmbaths, who submitted specimens to the Geological Survey for identification in August, 1937. Messrs. McCord Bros. prospected the deposit, and in 1939 it was worked on behalf of the Rev. D. Vermooten.

During the period March-August, 1940, the deposit was mined by Messrs. Geraghty and Eitzen on tribute. Mining operations, however, have been suspended.

(*c*) *Geology*.—Red granite outcrops in the vicinity of the fluorspar mine. Sheet 10 shows a major thrust fault cutting across the farm in a N.W.–S.E. direction. The distance between the mine and the nearest point on the surface trace of this thrust is one mile.

(*d*) *General.*—The fluorspar occurs as veins in the Red granite, the major vein striking E. 10° N. The veins range in thickness from mere stringers up to nearly 5 feet.

(*e*) *Description of the Workings.*—The workings lie on both sides of the Rietspruit, and those adjacent to the banks are liable to be flooded during periods of heavy rain, when the normally dry spruit flows. This happened a fortnight before the writer's visit and many of the excavations could not be examined.

The mine workings and prospecting pits are shown on the map (Fig. 1), which was prepared from compass and pacing traverses.

(i) *Main vein. "A" working.*—This is an open-cut 80 feet long, and 10 to 15 feet deep, which extends eastwards into a short stope connected to the surface by a small haulage shaft 25 feet deep. In this working the fluorspar vein, which ranges from 8 inches to about 5 feet in thickness, dips to the south at angles varying from 59° to 84°.

"B" Working.—This is a large open-cut 130 feet long and on the average 20 feet wide and 6 to 15 feet deep. The vein could not be inspected as the cut was flooded.

A prospecting pit 80 feet east of "A" working intersected two veins of fluorspar which dip to the south at 82°. The veins, which are separated by 9 inches of granite, are 27 inches and 9 inches thick respectively.

Trench b did not intersect any fluorspar, while in b^1 the vein is only 2 to 6 inches thick.

(ii) *Subsidiary Veins.*—In "C" working, which consists of an open cut 25 feet long and 17 feet deep, four separate veins were located. At the eastern face of the cut the section from north to south is :—

1 foot fluorspar.
7 inches granite.
6 inches fluorspar.
5 inches granite.
1 foot fluorspar.

On the N. side of the cut a little undercutting has disclosed the presence of yet another fairly thick vein.

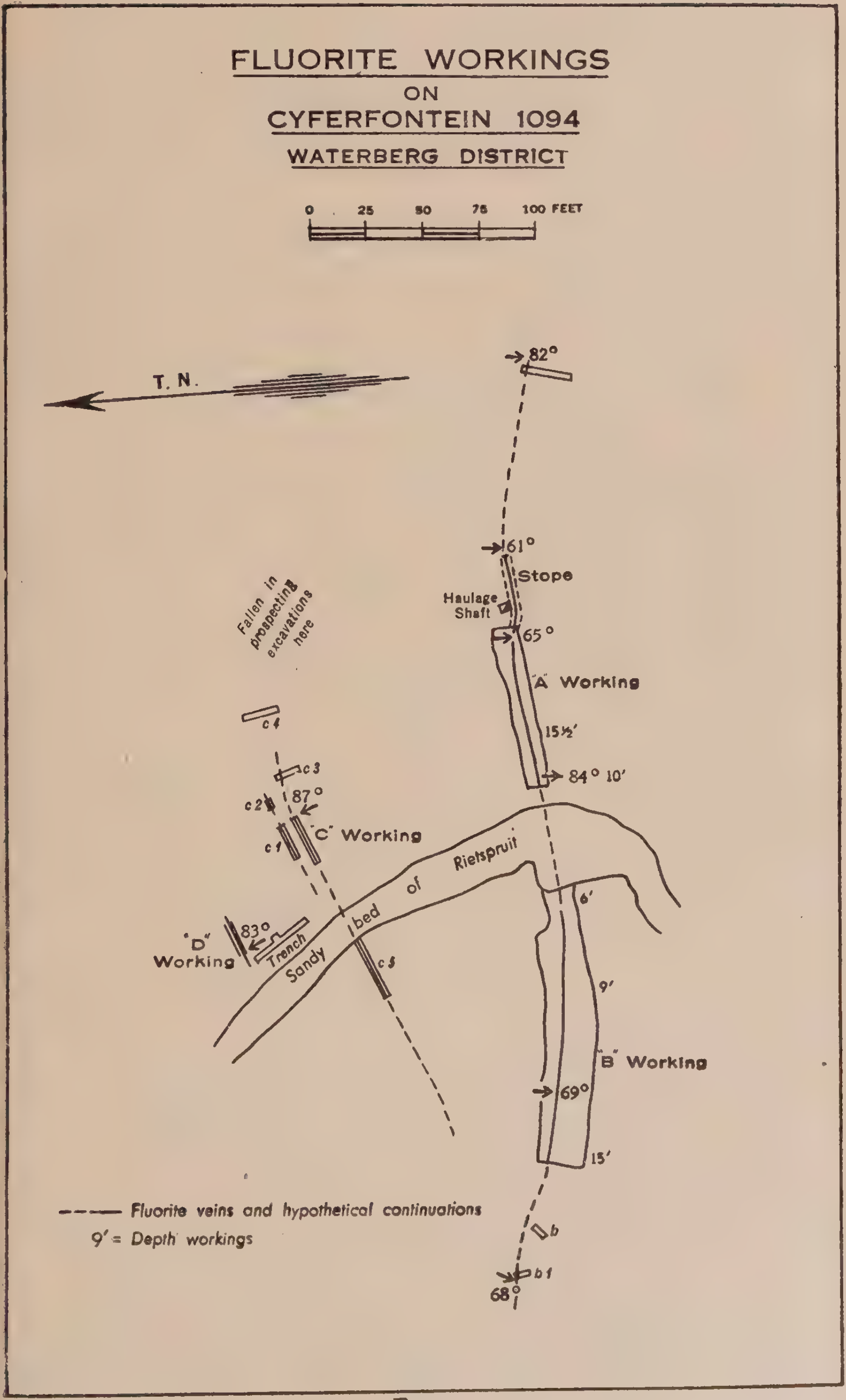
These veins dip northwards at 87°. The nearby trench c^1 exposes a vein of fluorspar 15 inches wide. Prospecting excavations c^2, c^3, and c^5 located veins 12 inches, 19 inches, and 16 inches thick respectively.

"D" working exposed a vein 7 inches thick dipping to the north at 83°.

This evidence indicates that future development should be concentrated on the main vein.

Prospecting and mining operations generally have been seriously impeded by the excessive overburden which has to be penetrated and removed. This overburden, which ranges in thickness from a few inches to 10 feet, is alluvial in origin near the spruit and eluvial elsewhere. The masked fluorspar veins have been located and traced by trenches and test pits.

The total production of fluorspar by Geraghty and Eitzen is stated to have been about 100 tons.



FLUORITE WORKINGS
ON
CYFERFONTEIN 1094
WATERBERG DISTRICT

Fig. 1

(*f*) *The Ore.*—The principal impurity is unreplaced granite. This, however, is usually present in tiny pieces and quite commonly the mine faces inspected were free of it. Quartz is very rare.

Fortunately, in most of the uses to which fluorspar is put, granite fragments are merely a diluent and are not harmful if present in small amounts. Deleterious impurities such as metallic sulphides, sulphates and chlorite were not observed either in the workings or in the ore stacked on the dumps.

(*g*) *Origin of the Ore.*—There is definite evidence that the fluorspar veins fill fissures that are true faults. For example, in "A" working where the hanging-wall granite is exposed it exhibits practically vertical slickenside grooves. In c^5 prospecting cut a more basic rock in the Red granite has been cut off by the fluorspar-filled fissure. The veins themselves show clear evidence of several renewals of movement along the fissures, which resulted in the brecciation and recementation of earlier-formed fluorspar. (See p. 9)

Apophyses project from the veins into the granite. In many places, too, there is a gradation through an inch or two of fluorspar-veined and -impregnated granite to unmineralised granite. This shows that there was replacement of granite as well as fissure filling.

It is problematical whether the fluorspar is a late magmatic deposit genetically associated with the Red granite, or with a later hidden body of alkaline rock, or whether it is younger still. With regard to this latter possibility, the fissures may have formed at the same time as the nearby fault, and the fluorspar may have been deposited by hot water ascending along them.

At Ojo Caliente, New Mexico, a vein of colourless fibrous fluorspar—associated with limonite and oxides of manganese—occurring in red gneiss, is considered* to be filling a former conduit of the nearby sodium carbonate-rich hot springs. Tufa deposited by these springs contains 0·9 per cent. fluorspar. It is significant that the hot spring in the Red granite at Warmbaths, which issues from a fault-fissure associated with the fault that passes through Cyferfontein, is also rich in sodium carbonate and fluorine.

(*h*) *Summary and Conclusions.*—(i) The quality of the fluorspar is fairly high and it is free from such deleterious impurities as metallic sulphides, barite, etc.

(ii) None of the veins have been fully traced either at the surface or at depth. All are lenticular.

(iii) The workings situated on the banks of the spruit are always liable to be flooded.

(iv) The length of strike of the main vein is at least 400 feet and its average width is 3 feet. Assuming a depth persistence to 50 feet, the ore reserves are estimated at 5,000 tons. (L. E. K.)

2. TOOYSKRAAL 282, WATERBERG DISTRICT

(*a*) *Locality.*—This farm is 27 miles west of Warmbaths, the nearest railway station, and is traversed by the road connecting this village with the Leeuwpoort tin mines. The fluorspar occurrence lies half a mile north of the place where the road crosses the only causeway on the farm. (Fig. 2.)

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* LINDGREN, W.—"The Hot Springs at Ojo Caliente and their Deposits." *Econ. Geol.*, 5, 1910, *pp.* 22–27.

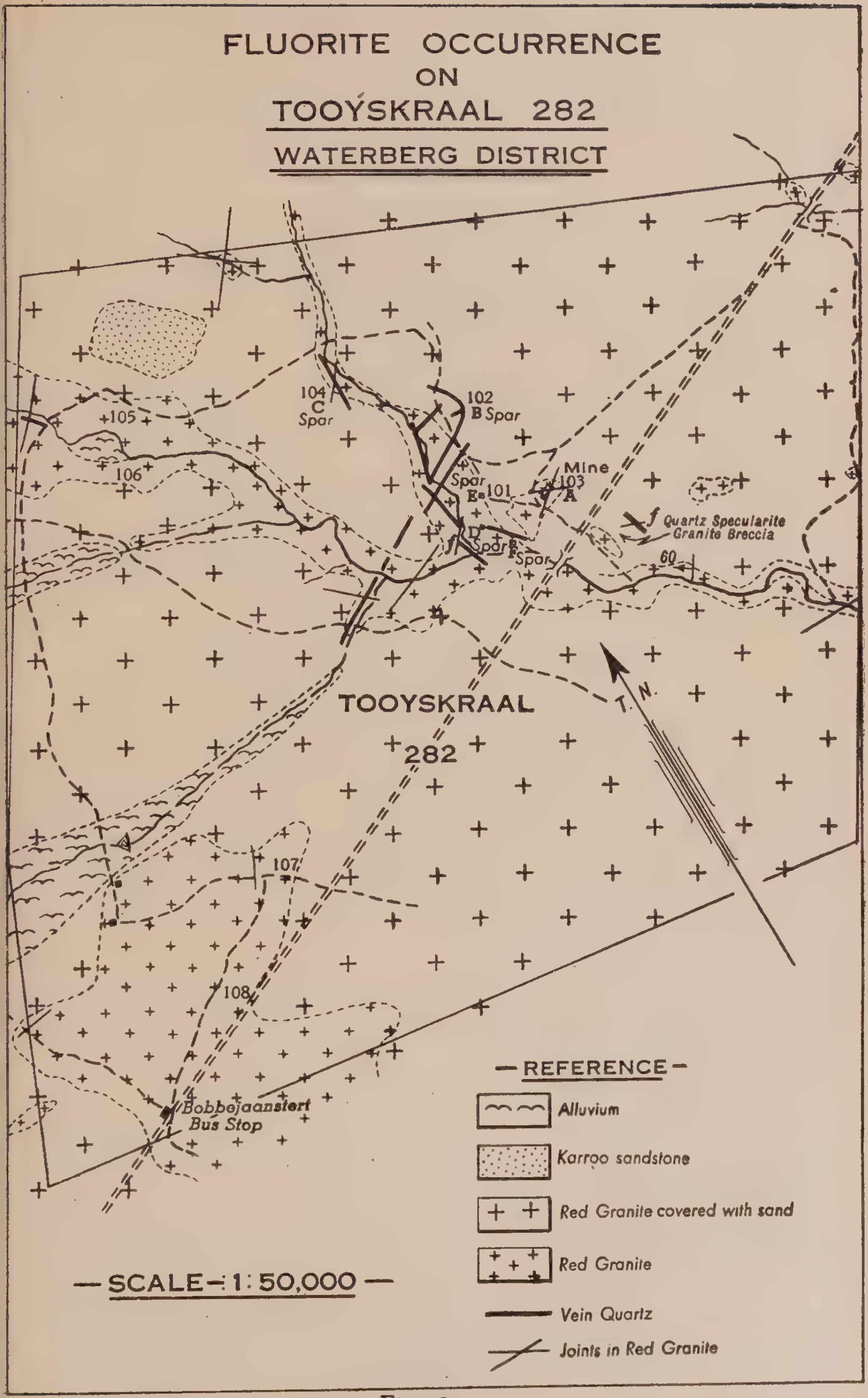
FLUORITE OCCURRENCE
ON
TOOYSKRAAL 282
WATERBERG DISTRICT
105
106
104
C
Spar
102
B Spar
Mine
103
A
Spar
E 101
D
Spar
Spar
Quartz Specularite Granite Breccia
60
T.N.
TOOYSKRAAL
282
107
108
Bobbejaanstert
Bus Stop
— REFERENCE —
Alluvium
Karroo sandstone
Red Granite covered with sand
Red Granite
Vein Quartz
Joints in Red Granite
— SCALE — 1: 50,000 —

Fig. 2

(*b*) *History.*—When and by whom this fluorspar occurrence was discovered could not be ascertained. Production took place for the first time in 1926, when 950 tons were produced by the Mabula Fluorspar Co. From 1926 to 1929 the Johnson Co. produced 4,680 tons valued at £9,583. During the years 1935–1937 Fluorite and Minerals (Pty.), Ltd., by working only the dumps, recovered 1,948 tons.

(*c*) *Topography and Drainage.*—The surrounding country is broken by ridges and dales. The ridges tend to lie parallel to one another and here and there a koppie stands out from them. Two sandy spruits cross the farm in a southerly direction and link up approximately half a mile north of the causeway to form a tributary of the Pienaars river.

A shallow hole in the sand of these spruits would yield a sufficient supply of water for mining purposes. The farm natives say that even in the driest season a good supply can be obtained in this manner.

(*d*) *Geology.*—Except for a patch of possibly Karroo sandstone, which can be recognised only by the colour of the sand and the presence of some light blue sandstone fragments, the country formation is Red granite. Outcrops are scarce and the remaining parts of the farm are covered by a coarse-grained sand consisting mainly of quartz and felspar particles.

Alluvium is found in two shallow valleys between the ridges in the north-western part of the farm. Ferricrete occurs here and there.

The surface covering of sand makes a thorough study of the granite impossible. Granite pophyry was noticed on the southern part of the farm which lies between the main road and the eastern sandy spruit, and pegmatites and secondary quartz veins were found extending in practically every direction. The pegmatite, consisting of microperthite and quartz, is very coarse and is referred to locally as "elephant granite". In some places muscovite is found in it. In the eastern spruit there are felspar masses 14 feet across. The quartz crystals are just as large.

(*e*) *The Occurrence.*—Poor mining methods have left the deposit in a hopeless condition, and the geological features could be determined only with the greatest difficulty. (Fig. 3.) The floors of the open quarries are largely covered with rubble and waste.

There are 5 rather irregular fluorspar veins striking at a small angle to the quartz vein in which they occur. There is little doubt that the fluorspar replaced the quartz, and was deposited in lenticular apertures made by the quartz vein.

The presence of haematite and specularite is important. The iron oxides were undoubtedly deposited after the fluorspar had been formed. In some cases the quartz is encrusted with haematite and the presence of seemingly large quantities of iron ore is impressive, but close inspection revealed that only a thin layer of oxides covers the quartz. Specularite occurs only along joints and cracks in the fluorspar and the parent rock. It is doubtful whether the iron ore has a deleterious effect on the local marketing of the fluorspar.

Sulphides have not been noticed in this deposit but in one of the old abandoned drives of the mine a green mineral, identified as chalcanthite ($CuSO_4 . 5H_2O$), was found as a crust on the fluorspar.

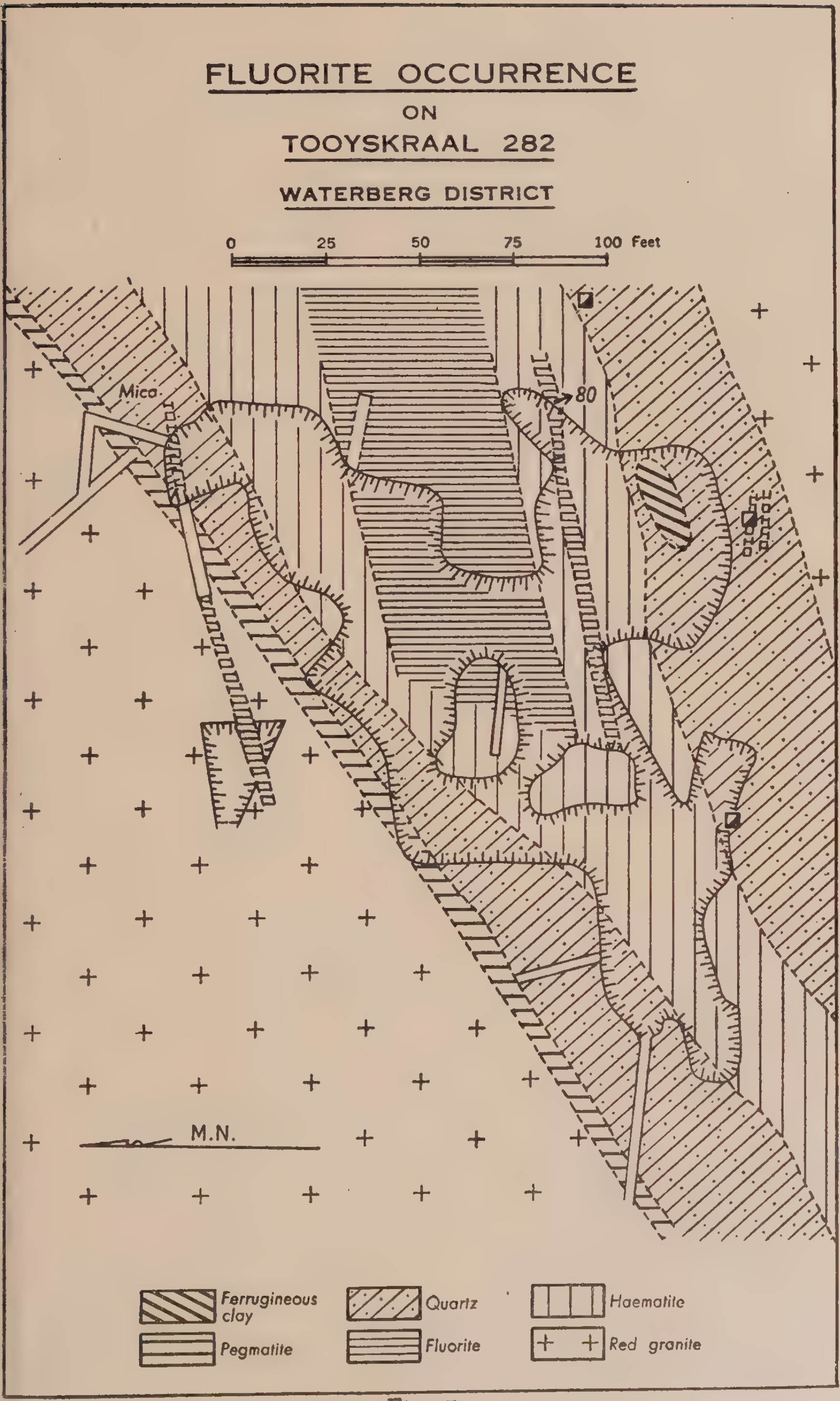
FLUORITE OCCURRENCE
ON
TOOYSKRAAL 282
WATERBERG DISTRICT
0
25
50
75
100 Feet
Mica
80
M.N.
Ferrugineous clay
Quartz
Haematite
Pegmatite
Fluorite
Red granite

Fig. 3

Chalcanthite is formed by the oxidation of chalcopyrite or, as most probably in this case, by deposition from mine water in old abandoned workings.

The prices mentioned above indicate that the fluorspar mined here was of good quality.

Water has been struck in the mine at a depth of 36 feet. This will increase production costs very considerably.

According to Kupferbürger* the fluorspar was mined to a depth of 60 feet, the product containing 95–96 per cent. CaF_2.

The ore remaining in the mine consists of fluorspar with quartz and specularite as impurities. It is improbable that the deposit will be further mined unless a market is found locally for the impure ore, the reserves of which are placed at 6,500 tons. By means of careful concentration the fluorspar could be raised to a quality suitable for export, but it is doubtful if this operation would pay.

(*f*) *Summary.*—(i) The deposit lies twenty-seven miles from Warmbaths and half a mile from the Road Motor Services' route connecting this village with the Leeuwpoort tin mines.

(ii) Ore reserves are estimated at 6,500 tons. The quality of the ore is approximately 75 per cent. CaF_2.

(iii) Water has been struck in the mine at a depth of 36 feet and will increase production costs considerably.

(iv) Owing to the large quantity of quartz associated with the ore the concentration of the fluorspar will be a difficult matter.

(v) Unless a market for the impure ore is found the occurrence will have no economic value.

3. RUIGTEPOORT (GOUDKOPPIES) 1373, WATERBERG DISTRICT (GILSPAR MINE)

(*a*) *Locality.*—The farm, in the south-western corner of the Waterberg district, is about 50 miles from Warmbaths and 50 miles north of Brits. The ore is transported by motor trucks to the nearest railway siding, Corona, on the Brits-Beestekraal extension, a distance of 40 miles. (Fig. 4.)

(*b*) *Topography and Drainage.*—The surrounding country is similar to that of Tooyskraal 282.

(*c*) *History.*—Old workings, containing stone hammers and other implements, have been opened in the mine. They are filled with fluorspar fragments and it is obvious that the prehistoric workers did not mine the fluorspar, but recovered only the specularite, which they ground to powder and probably smeared on their bodies.

During 1909–1912 Europeans settled in this locality and discovered gold in thin quartz veins—hence the name Goudkoppies. Subsequently gold claims were pegged here, and through this the fluorspar was discovered. The Warmbaths Fluorite Syndicate first worked the deposit and during the two years 1929–1930, 441 tons of fluorspar were produced. Production then ceased but was begun again in 1936 by Fluorite and Minerals (Pty.), Limited. The min develope drapidly and 6,826 tons were produced in 1939.

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* Unpublished Report.

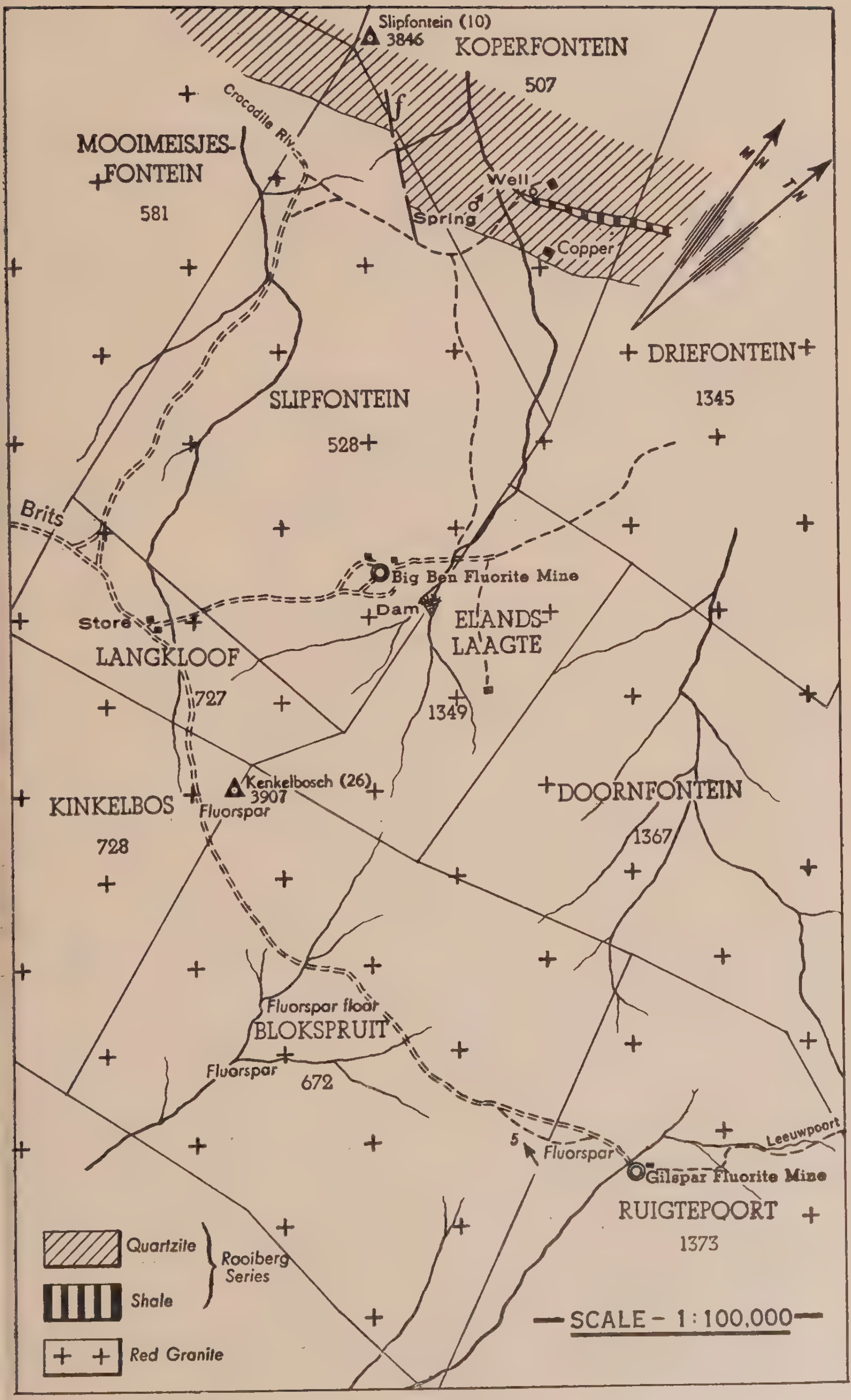


Fig 4.—Sketch map sdowing Flourspar occurrences on Ruigtepoort 1373 and Slipfontein 5_8.

(*d*) *Geology.*—The Red granite that underlies this area is of a very uniform nature. It gives a monotonous appearance to the surrounding country, which is characterised by low koppies and large rocky sheets sometimes covered by a thin layer of sand.

The granite is commonly coarse-grained and consists mainly of quartz and felspar in more or less equal proportions. Biotite is present in minor quantities and is sometimes considerably altered.

Most of the felspar consists of microperthite formed by intimate intergrowth of cloudy orthoclase and relatively clear plagioclase.

(*e*) *The Occurrence.*—The fluorspar occurs along the eastern side of a north-south trending valley. The mine consists of a large open-cast quarry with underground workings along its southern side. (Plate II.)

Apparently the fluorspar body is a replacement deposit, pipe-like in form. During its later phases the magma of the Red granite came into contact with the Transvaal dolomite and at this period, or shortly afterwards, the final phase of differentiation escaped in the form of volatile gases. The temperature fell considerably and fluorspar was formed. The deposit may have been enriched at a later stage through the action of hot waters which had chloritised the previously unreplaced granite.

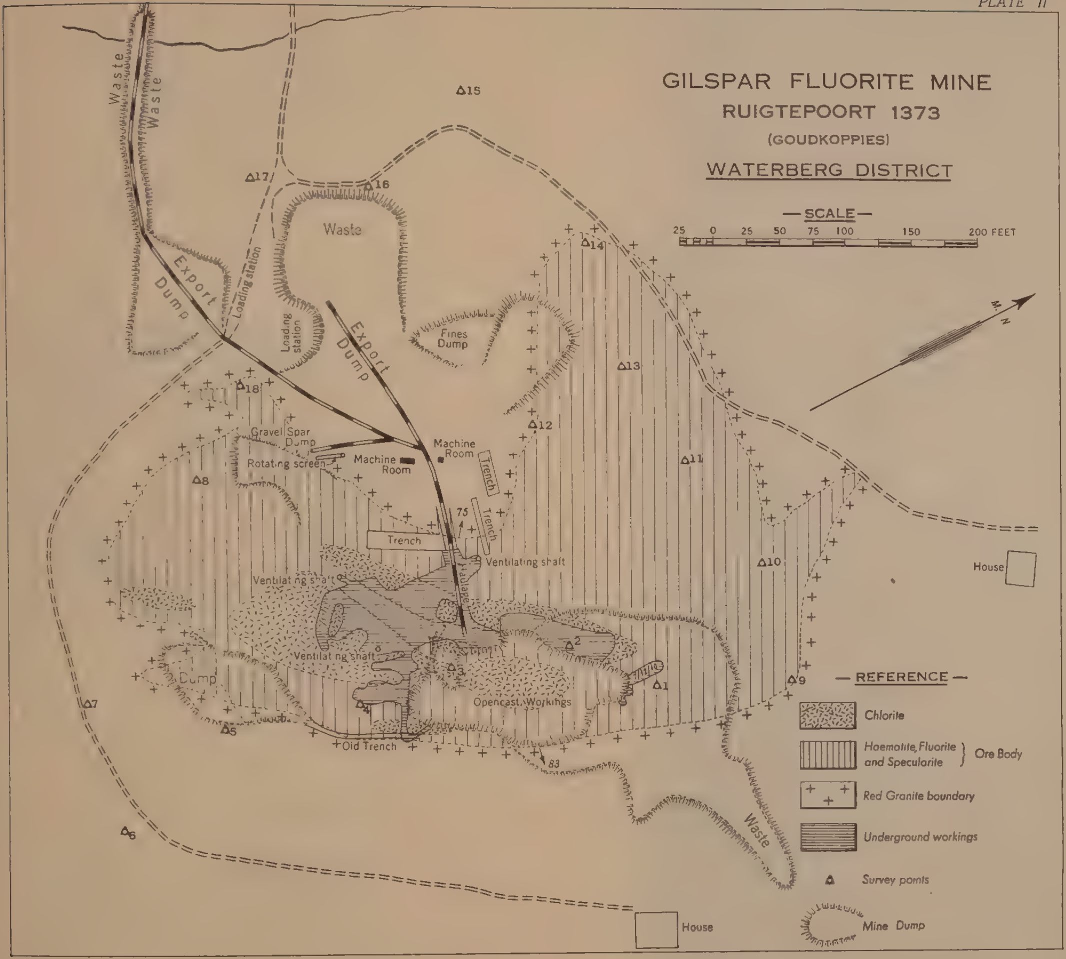
Considerably less quartz is to be found at this locality than at Tooyskraal 282 ; moreover, no pegmatite has been observed.

Thus far the contact of the ore body with the granite has been exposed only along the eastern side, and here the contact dips at an angle of 83° to the east. Consequently it is difficult to determine the form of the ore body. In and around the mine a chloritic rock containing fluorspar occurs. The boundaries of this rock are shown on the plan of the mine (Plate II) and it is considered that they indicate the shape of the ore body. Boreholes around the mine will be the best means of determining the size and shape of the ore body.

In the mine itself is a vertical joint along which movement took place. Apparently the joint had no part in the process of mineralisation as it cuts through the fluorspar and chlorite rocks. In addition, there is a nearly horizontal plane of movement characterised by a fluorspar-chlorite breccia. Directly beneath this plane apertures occurred which have been filled with a " finely stratified ferruginous clay in which no fluorspar can be seen ". (Mr. J. E. de Villiers, Geological Survey laboratory.) This clay was probably formed by infiltrating meteoric waters laden with minute clay particles. The extremely fine stratification of the clay indicates that practically no movement took place in the water while sedimentation was in progress and that the formation of the clay took place under the most favourable conditions. The clay has a conchoidal fracture and can be easily scratched with the finger nail.

The chlorite rocks occur as hanging masses in the fluorspar as well as along the sides of the ore body. They consist of quartz and chlorite and contain fluorspar in small quantities.

(*f*) *Exploitation.*—The ore is broken in the mine by blasting and taken in cocopans to the various sorting stations where, if necessary, it is broken by hand into smaller sizes.



GILSPAR FLUORITE MINE
RUIGTEPOORT 1373
(GOUDKOPPIES)
WATERBERG DISTRICT

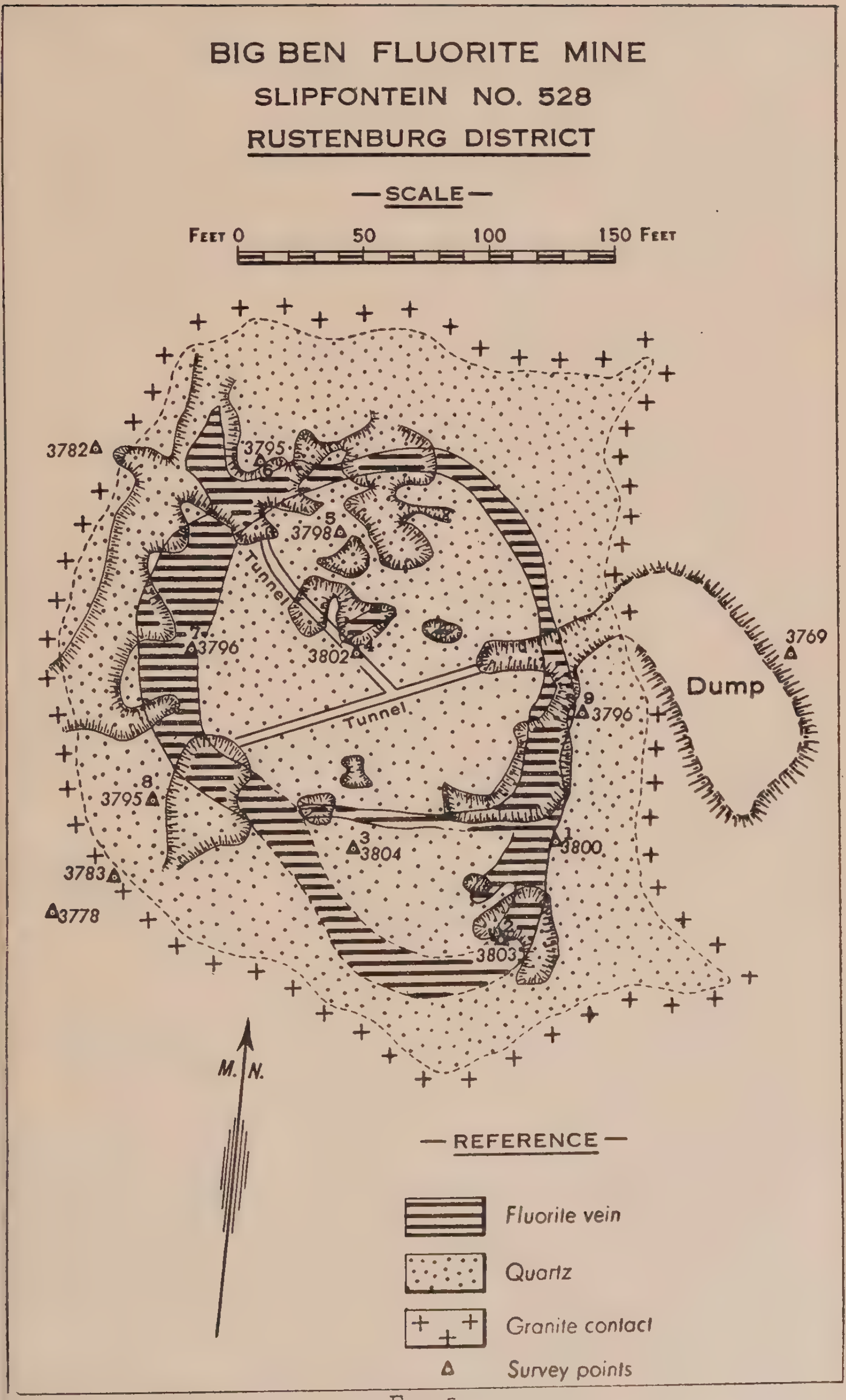

BIG BEN FLUORITE MINE
SLIPFONTEIN NO. 528
RUSTENBURG DISTRICT
— SCALE —
FEET 0
50
100
150 FEET
3782
3795
6
5
3798
Tunnel
7
3796
3802
4
Tunnel
3769
Dump
9
3796
8
3795
3
3804
1
3800
3783
3778
2
3803
M. N.
— REFERENCE —
Fluorite vein
Quartz
Granite contact
Survey points

Fig. 5

Fine material is sent through a rotating screen provided with the following apertures :—⅛ inch, ¼ inch, ½ inch, 1 inch. Material with a diameter of less than one-eighth inch is difficult to concentrate, and for this a pneumatic table is recommended.

The mining methods employed are not only wasteful but may be fatal. Probably the best results will be obtained if the mine is developed as a large open-cast working. At present pillars of almost pure fluorspar are left to support the roof of the underground workings ; consequently a large amount of fluorspar is wasted and despite this the roof is very dangerous in places. It is still possible to blast the roof down but as the underground workings are deepened this will become increasingly dangerous.

(*g*) *Production.*—During the years 1936–1940, 15,292 tons were produced.

(*h*) *Summary.*—(i) The deposit is forty miles N.N.E. of Corona, the nearest railway siding.

(ii) Ore reserves are estimated to be 400,000 tons, but may be considerably less because of the chlorite present.

(iii) Water is encountered at a depth of 35 feet, but as there is a shortage of water in the locality this is not a disadvantage.

(iv) The deposit is considered the largest in South Africa.

4. SLIPFONTEIN 528, RUSTENBURG DISTRICT (BIG BEN MINE)

(*a*) *Locality.*—This deposit is in the north-eastern corner of the Rustenburg district, and approximately four miles north-west of the Gilspar mine on Ruigtepoort 1373. (Fig. 4.)

(*b*) *History.*—The occurrence was discovered by Mr. R. W. van Rensburg in 1936 and production started in 1939. During the years 1939–1940, Fluorite and Minerals (Pty.), Ltd., produced 3,315 tons of fluorspar valued at £6,610.

(*c*) *Geology.*—The geology of the locality is similar to that of Ruigtepoort 1373.

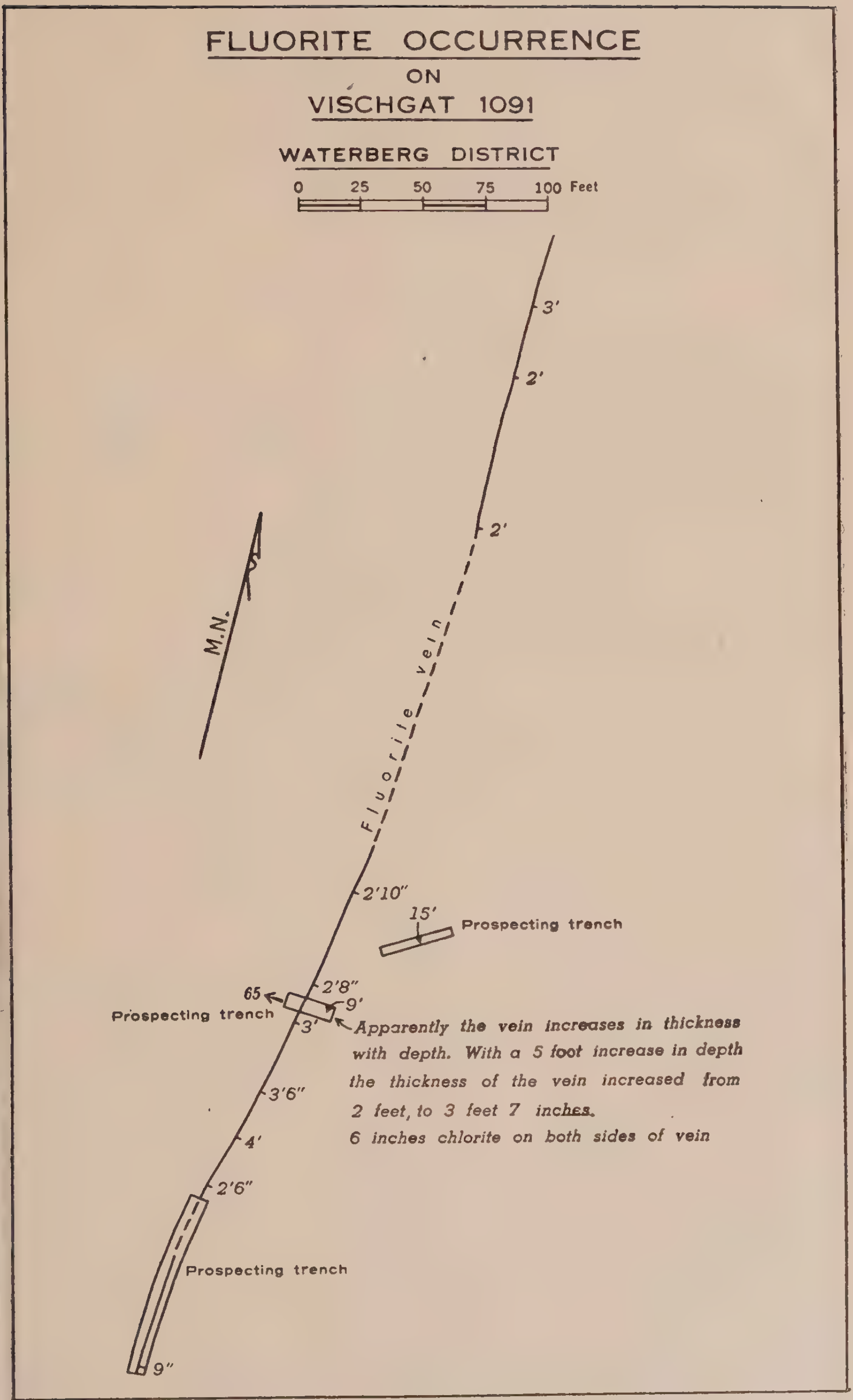
(*d*) *The Occurrence.*—The deposit is ring-shaped and occurs in a pipe-like quartz body which forms an isolated koppie in otherwise flat country. (Fig. 5.)

The fluorspar vein sends tongue-like shoots into the quartz, which it doubtless replaces.

The vein has been located at both ends of a tunnel driven through the koppie. (Fig. 5.) A second tunnel branches off from the middle of the first and cuts through the vein at the point where it emerges at the side of the koppie. In the tunnels themselves no fluorspar of any importance has been found. The vein can be traced comparatively easily on the surface.

Development here has been very unsystematic and at many points the waste material has been dumped right on top of the vein. Many unnecessary trenches and pits have been dug.

If development is confined to the fluorspar it will be possible to increase production considerably without much trouble.



Apparently the vein increases in thickness with depth. With a 5 foot increase in depth the thickness of the vein increased from 2 feet, to 3 feet 7 inches.

6 inches chlorite on both sides of vein

Fig. 6

The circumference of the ring-shaped vein is 500 feet with an average thickness of 5 feet. If the vein continues to a depth of 50 feet an additional 12,500 tons of fluorspar may be produced here.

On the map (Fig. 5) the width of the vein is enlarged three times.

(*e*) *Summary.*—(i) Big Ben Mine is approximately thirty-five miles from Corona, the nearest railway siding.

(ii) The ore body consists of a ring-shaped vein in a pipe-like quartz body in the Red granite.

(iii) Ore reserves are estimated to be 12,500 tons.

5. VISCHGAT 1091, WATERBERG DISTRICT,
and
6. BUFFELSFONTEIN 969, POTGIETERSRUST DISTRICT

(*a*) *Locality.*—This area lies to the west of the Great North Road and the railway line, and immediately south of latitude 24° 30′. Vischgat 1091 is eight miles south-west of the village of Naboomspruit and two miles west of the Great North Road. Buffelsfontein 969 is four miles north-west of Naboomspruit. (Plate III.)

(*b*) *History.*—After the discovery of platinum in the Bushveld complex, prospectors searched far and wide for this metal, and most of the prospecting pits and trenches in the Red granite on Vischgat 1091 were dug for this purpose.

On the farm Buffelsfontein 969 a shallow excavation was made in a small fluorspar body, but nothing could be ascertained concerning its origin.

(*c*) *Topography.*—The area borders partly on the northern edge of the Springbok flats and may be subdivided into the plateau of sandstone, the mountainous country of felsite and the Flats of sandstone covering the granite.

(*d*) *Geology.*—(i) Red granite—Bushveld igneous complex.
(ii) Felsites—Rooiberg series.
(iii) Sandstone—Karroo system.
(iv) Structural features.

(i) *Red Granite.*—The Red granite is relatively coarse and similar to that on Ruigtepoort 1373. Pegmatites occur on Buffelsfontein 969 immediately above a large number of fluorspar-filled joints.

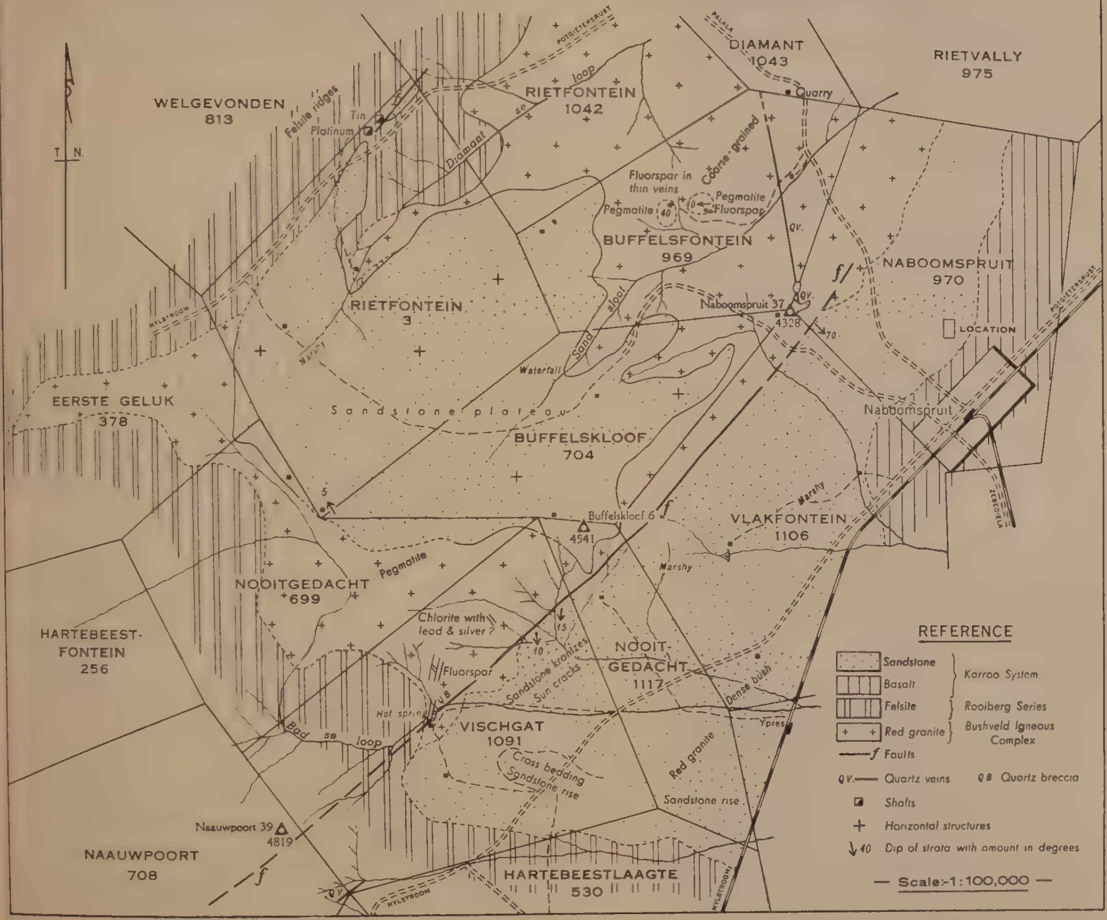
(ii) *Felsites.*—The felsites disintegrate into yellowish-brown angular fragments which cover the slopes of the hills. Nothing of economic importance was found in the felsites in this area.

(iii) *The Sandstone.*—The weathered surface of the sandstone is red in colour. On the farm Buffelsfontein 969 a thin layer of conglomerate lies between the sandstone and the granite. Most of the pebbles consist of quartz and granite. In the western part of the area the sandstone directly overlies the felsites.

(iv) *Structural Features.*—The sandstone has been thrown down vertically approximately 400 feet in a S.E. direction by a rather large fault striking N.E.-S.W. The fault escarpment has weathered away considerably, and the Red granite has been exposed. (Plate III.) Some distance from where the spruit, Bad se Loop, crosses the fault is a warm spring. The warm water and gas emerge along a north-south striking brecciated zone which forms an angle of about 30° with the trace of the fault plane. The warm spring lies at the lowest level on the trace of the fault plane.

PLATE III

FLUORSPAR OCCURRENCES ON VISCHGAT 1091 AND BUFFELSFONTEIN 969



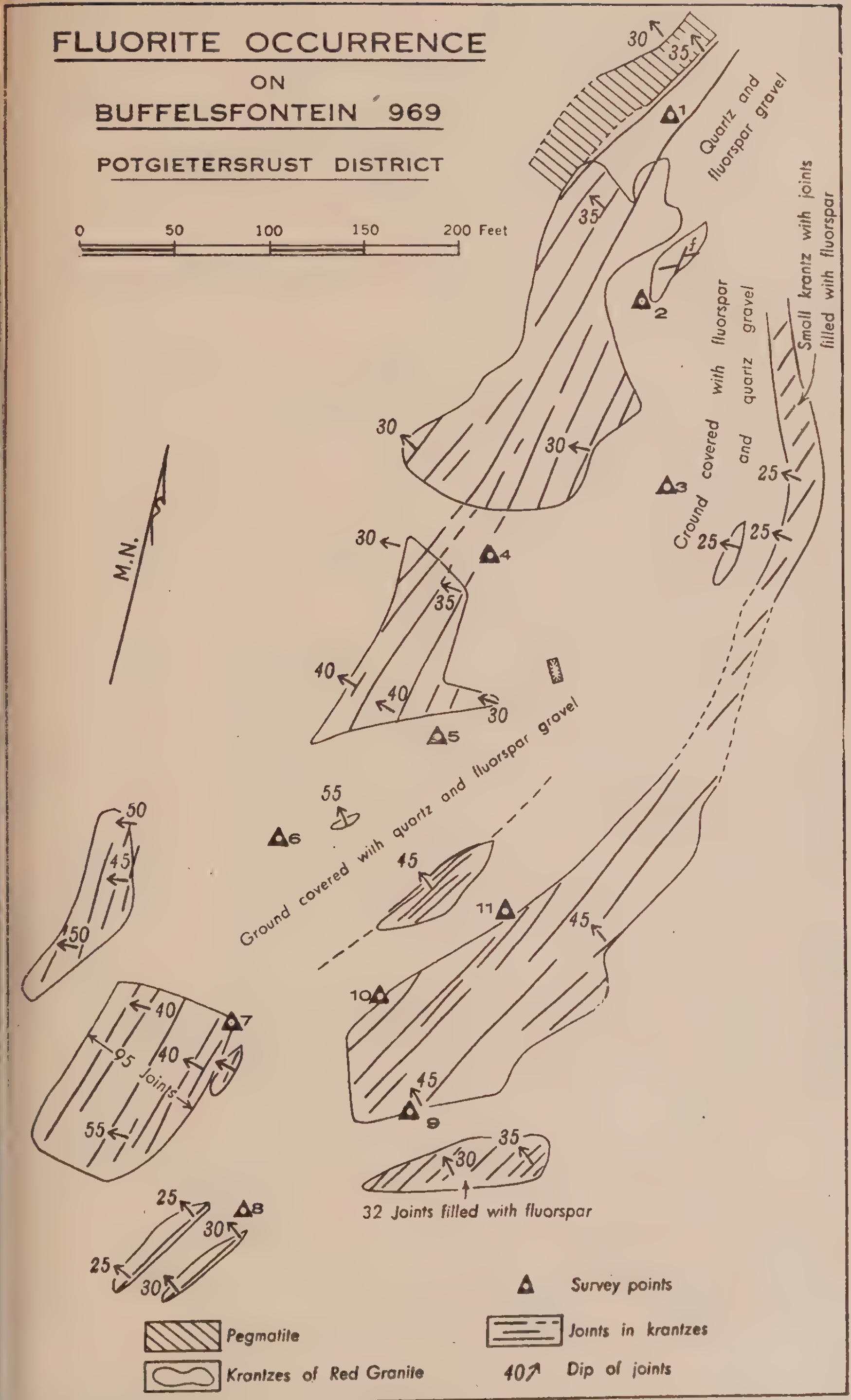

FLUORITE OCCURRENCE
ON
BUFFELSFONTEIN 969
POTGIETERSRUST DISTRICT
0
50
100
150
200 Feet
M.N.
Quartz and fluorspar gravel
Small krantz with joints filled with fluorspar
Ground covered with fluorspar and quartz gravel
Ground covered with quartz and fluorspar gravel
95 Joints
32 Joints filled with fluorspar
1
2
3
4
5
6
7
8
9
10
11
30
35
35
30
30
30
35
40
40
30
25
25
25
55
50
45
50
45
45
45
40
40
55
35
30
25
30
25
30
Pegmatite
Krantzes of Red Granite
Survey points
Joints in krantzes
40 Dip of joints

Fig. 7

The warm water may be derived from surface water percolating down the fault plane to a great depth, and being forced up the brecciated zone by hydrostatic pressure.

The fault has caused a considerable number of shear zones in the Red granite. Most of these zones strike about north-south and lie at an angle of approximately 30° to the fault plane, but some are nearly perpendicular to it. Mineralisation took place along these shear zones.

(*e*) *The Occurrences.* (i) *Vischgat* 1091.—A fluorspar vein occurs in Red granite about $1\frac{1}{2}$ miles north of the warm spring. The vein, which is 450 feet long and averages 3 feet in width, strikes 5° east of north and dips at a steep angle in a westerly direction. (Fig. 6.) In a pit 7 feet deep the vein increased in thickness from 2 feet to 3 feet 7 inches, thus it is possible that the thickness may increase with depth. Chlorite seams six inches thick occur on both sides of the vein. Apparently the granite here was chloritised simultaneously with the formation of the fluorspar.

No production has as yet taken place. It is recommended that development be confined to the fluorspar vein.

The ore reserve is estimated at 6,700 tons assuming that the vein persists to a depth of 50 feet.

(ii) *Buffelsfontein* 969. The occurrence is an interesting one. Some krantzes of Red granite on top of a koppie are closely jointed. (Fig. 7.) Each joint is filled with fluorspar and the veins so formed range in thickness from a fraction of an inch to 5 inches. The joints dip in a westerly direction at angles averaging 40°. Higher up in the zone occurs a pegmatite " layer ", approximately 5 feet thick, and dipping in the same direction as the joints. No fluorspar is encountered above the pegmatite.

The fluorspar weathers comparatively easily out of the joints and the surfaces below the krantzes are covered with the fragments.

Some prospecting took place recently on this farm, and the eastern face of an old quarry which was cleaned out showed numerous intersecting fluorspar veins.

In the centre of the quarry two rather prominent joints striking north and 30° east of north intersect. These joints are filled with brecciated fluorspar, showing that some movement took place after the mineralisation.

In the quarry a fluorspar body, dipping at 35° to the west, is encountered 20 feet below the surface. This body is $3\frac{1}{2}$ feet thick and is visible for 20 feet; the lateral limits, however, are not exposed. Development seems advisable.

Recent activities have resulted in the production of 100 tons and another 25 tons are lying at grass.

A few boreholes along the western edge of the krantzes might reveal the presence of a larger ore body.

7. GROBBELAARS HOEK 785, POTGIETERSRUST DISTRICT

(*a*) *Locality.*—Grobbelaars Hoek lies eighty miles north-west of Potgietersrust. The deposit is near the northern boundary not far from the north-western beacon of the farm. (Fig. 8.)

(*b*) *History.*—The first production figures are given for 1938 when Fluorite and Minerals (Pty.), Ltd., produced 77 tons valued at £228.

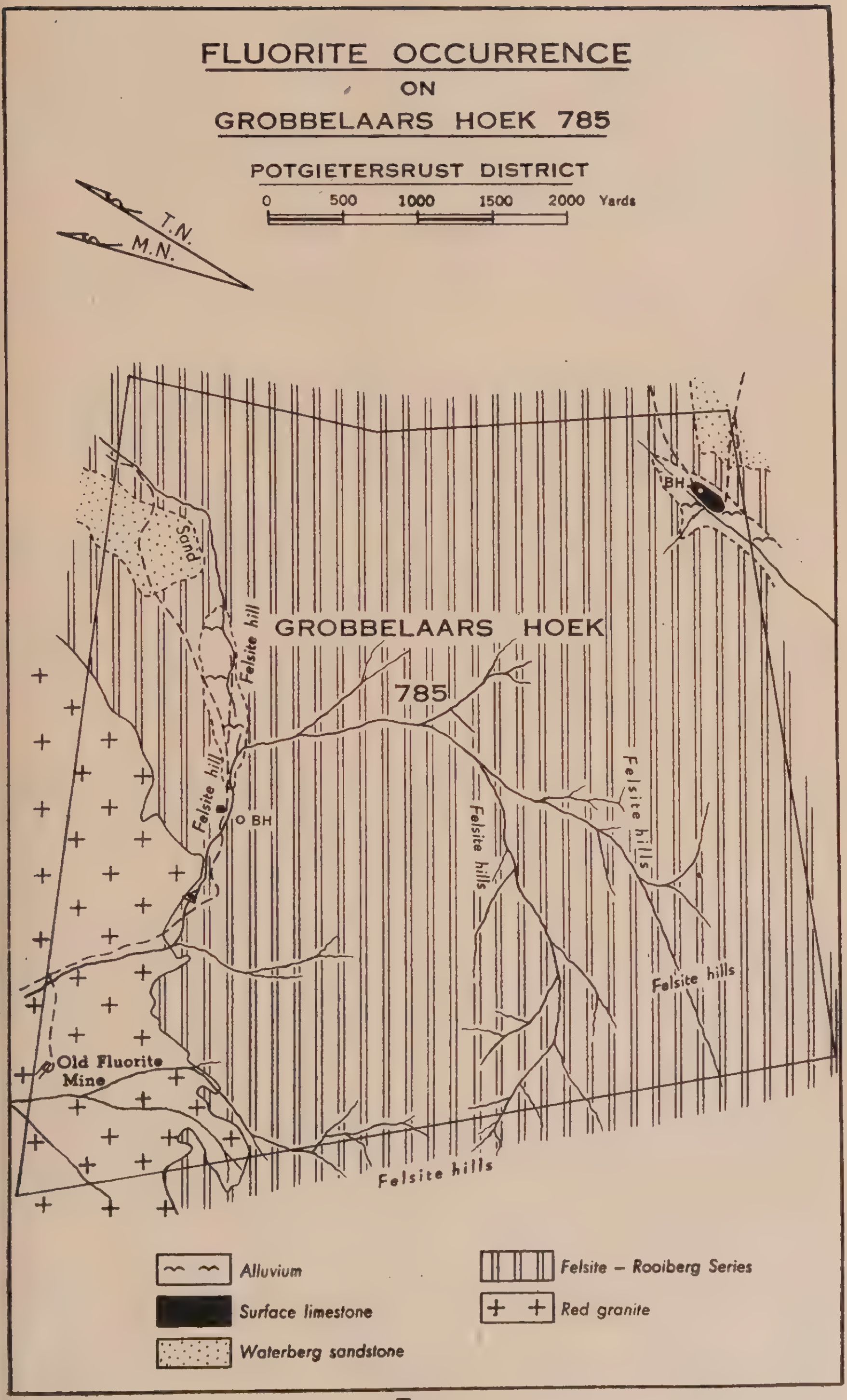

FLUORITE OCCURRENCE
ON
GROBBELAARS HOEK 785
POTGIETERSRUST DISTRICT
0
500
1000
1500
2000
Yards
T.N.
M.N.
Sand
Felsite hill
Felsite hill
GROBBELAARS HOEK
785
BH
BH
Felsite hills
Felsite hills
Felsite hills
Felsite hills
Old Fluorite Mine
Alluvium
Surface limestone
Waterberg sandstone
Felsite – Rooiberg Series
Red granite

Fig. 8

In 1939 James Martin and McGill recovered an additional 64 ton valued at £204. Since then there has been no further production.

(*c*) *The Occurrence.*—The workings, which are 150 feet in length and strike E.-W., are covered by stagnant water and it was impossible to study the occurrence. The fluorspar here was apparently associated with quartz. Other fluorspar veins, half an inch thick, in granite near the workings also strike E.-W.

" The spar itself is very pure and assayed 99·4 per cent. CaF_2 on the contacts it was impregnated with silica.

" The occurrence is in the nature of a lens striking east to west. dipping 3° north, length of lens was 40 feet, width at surface 12 feet, depth 20 feet when the spar pinched out to a narrow vein 6–9 inches and dipped sharply to the north.

" It is not worked to-day and may be considered worked out."*

Dr. W. Kupferbürger reported that some of the fluorspar was blue when freshly broken but on exposure faded to a dull white.

8. VALSCHFONTEIN 432, PRETORIA DISTRICT

(*a*) *Locality.*—Valschfontein lies on the southern bank of the Elands river, approximately 20 miles up stream from where the Roedtan-Marble Hall main road crosses the river.

(*b*) *History.*—A sample of fluorspar from this occurrence was submitted by Mr. G. Kretzschmar to the Geological Survey for examination in April, 1934.

(*c*) *Geology.*—The farm is largely covered with sand and the geological structures could not be determined.

(*d*) *The Occurrence.*—The occurrence consists of fluorspar-barite-quartz veins. There are three veins, two of which are vertical, 33 feet apart and striking 10° north of east. The northern vein is 2 feet 4 inches thick and the southern one 3 feet 10 inches. They were traced for 200 feet along the strike.

A third vein is found half a mile west of the others. It strikes 10° north of east, dips at 65° in a southerly direction and can be followed for 100 feet along the strike. The thickness at the east end is 3 feet 6 inches but to the west it thins to 1 foot 6 inches. An excavation made on this vein is filled with water.

The occurrence is not of any economic value. (D. P. v. R.)

9. ANALYSES

Samples of fluorspar, considered to be representative of the deposits, were collected for analysis. (For Ruigtepoort see p. 66.)

	Tooyskraal.	Slipfontein.	Vischgat.	Buffelsfontein.
Ca	50·2	47·3	48·1	51·4
F	46·8	43·5	44·8	47·0
SiO_2	1·2	6·7	3·2	1·2
Fe_2O_3	1·7	1·0	2·8	0·2
Al_2O_3	0·5	0·3	1·0	0·3
MgO	Nil	Nil	Nil	Nil
Loss on Ignition	0·4	0·3	0·5	0·2
	100·8	99·1	100·4	100·3

Analyst: C. F. J. van der Walt, Division of Chemical Services.

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* Personal communication: Dr. G. H. Cock, Managing Director, Fluorite and Minerals (Pty.), Ltd.

10. CONCLUSIONS

The following are the most important occurrences in the Red granite :—

(*a*) *Ruigtepoort* (*Goudkoppies*) 1373, *Waterberg district.*—A pipe-like occurrence with possible ore reserves of about 400,000 tons. The chlorite masses occurring in the ore body must be taken into account, however, as they will decrease the available tonnage of fluorspar considerably.

(*b*) *Slipfontein* 528, *Rustenburg district.*—A ring-shaped vein occurrence in a pipe-like quartz body. The possible ore reserves are estimated at 12,500 tons. In this mine development should be confined to the vein.

(*c*) *Vischgat* 1091, *Waterberg district.*—A vein 450 feet in length with an average thickness of 3 feet. The ore reserves are estimated to be 6,700 tons. No production has taken place.

(*d*) *Buffelsfontein* 969, *Potgietersrust district.*—Owing to the large number of thin veinlets which comprise this occurrence it is impossible to estimate the ore reserves. A few boreholes to the west of the veinlets might locate an ore body.

(*e*) *Cyferfontein* 1094, *Waterberg district.*—The main vein has a length of 400 feet and its average thickness is 3 feet. The ore reserves are estimated at 5,000 tons.

(D. P. v. R.)

C. Occurrences in the Rooiberg Felsites

1. ROODEPLAAT 314, PRETORIA DISTRICT*

(*a*) *Locality.*—The farm is eighteen miles north-east of Pretoria. (Fig. 9.)

(*b*) *Geology.*—The fluorspar deposit occurs in an endogenetic volcanic breccia, in which fragmentation was caused by deep-seated volcanic forces. The breccia is a hard, red, massive rock composed of fragments and boulders, mostly of felsite and trachyte. It is problematical whether the breccias are of Rooiberg or post- Red granite age.

(*c*) *The Deposit.*—The numerous fluorspar grains in the volcanic breccia as well as in the flow-breccia, prove that the fluorspar vapours were associated with the intrusion of the breccia. "On the talus slope, to the south of (breccia) outcrop A, a few prospecting trenches, about six feet deep, were made in search of fluorite. At this depth the fluorite content of the weathered rock does not seem very promising, although lumps of the mineral of purple and white colours have been found apparently in the form of irregular veins traversing the rock. It is possible that the fluorite content may show an increase at greater depth. On the northern side of the breccia a few shallow trenches have also been opened up; here the weathered rock seems to be impregnated with minute grains of the mineral. In both cases, however, the trenches were too shallow to form any definite opinion as to the economic importance of the fluorite.

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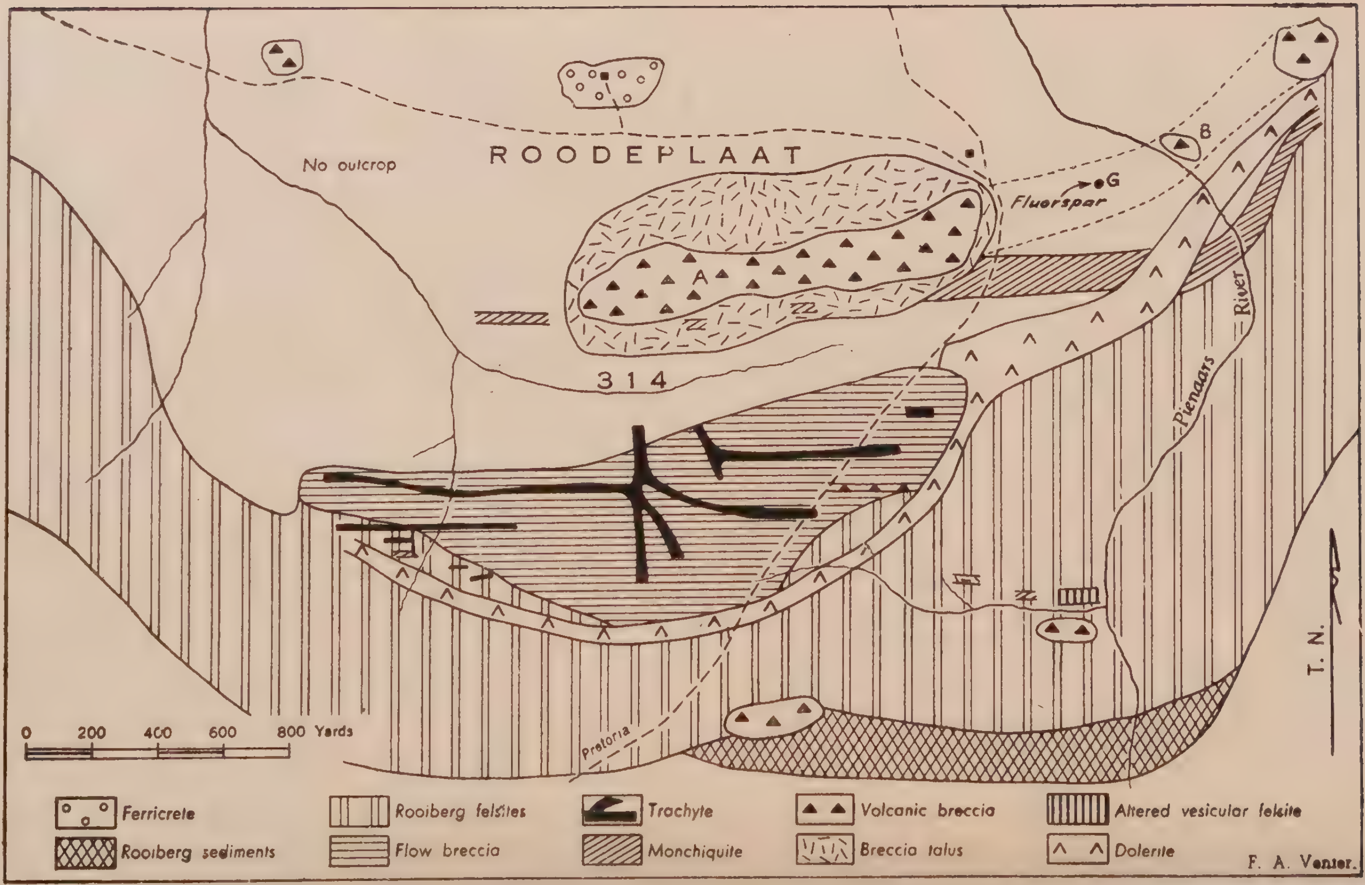
* Venter, F. A.—"Breccias and Associated Rocks occurring North-East of Pretoria." *Trans. geol. Soc. S. Afr., XXXVI,* 1933, *pp.* 49–50.


ROODEPLAAT
No outcrop
3 1 4
A
B
G
Fluorspar
Pienaars River
Pretoria
T. N.
0 200 400 600 800 Yards
Ferricrete
Rooiberg sediments
Rooiberg felsites
Flow breccia
Trachyte
Monchiquite
Volcanic breccia
Breccia talus
Altered vesicular felsite
Dolerite
F. A. Venter.

"In the area between the breccia outcrops A and B [Fig. 9], no exposures of fluorite are in evidence, but close to the farm house, and to the east of the main road, a deep circular hole was made at the locality marked G on the map, in search of the mineral, which was found in fair abundance. After a few tons of fluorite had been mined the hole was closed up for no evident reason, and on this account no further investigation as regards the nature of the occurrence could be carried out. From a few loose specimens obtained at the locality, the fluorite seems to be very pure and, if a fair quantity is available, it may be profitably exploited."

D. Occurrences Associated with Alkaline Rocks

Fluorspar frequently occurs in certain of the bodies of alkaline igneous rocks in the Transvaal. Most of the deposits are of little economic importance as apatite is generally present in intimate association with the fluorspar.

I. OCCURRENCES IN THE PILANSBERG

Fluorspar occurs at several localities in the alkaline complex of the Pilansberg. Shand,* in his paper on the complex, wrote :—

> "Fluorspar was being mined on an experimental scale on Wydhoek and Nooitgedacht when I was in the Berg in 1925, but the deposits are too patchy and impure to be worth attention, and, although the mineral is widely distributed in the Berg, I found no indication of any workable deposit."

(*a*) *Wydhoek* 701.—The deposit mentioned by Shand is located on the southern slopes of a steep hill, about half a mile north of the road from Rustenburg to Saul's Poort.

The fluorspar occurs as a vein 12 to 15 feet wide in a medium-grained white foyaite. Thin apophyses penetrate the country foyaite in the immediate vicinity. On Shand's map, however, the mine is shown in lavas, but this was doubtless due to the obscuring effect of the scree on the steep slopes.

The vein, which has been exposed for about 80 feet in a small quarry, strikes east-west and dips to the north at an average of 80° ; because of the obscuring rubble overburden it could not be traced beyond the confines of the quarry. The thickness, however, suggests that the lateral extent should be of the order of hundreds of feet.

This deposit has been known for many years and has been worked from time to time. Formerly a chute was employed to convey the fluorspar from the quarry to a rough track at the bottom of the hill. About 150 tons were estimated to be at grass in 1941.

The vein has a banded appearance due to the presence of persistent streaks of fluorspar containing much white apatite and felspar. These streaks, which range from about 1 to 3 inches in thickness, run parallel to the strike of the vein and also dip steeply to the north.

The fluorspar itself is dark purple save on the outcrops, where it has been bleached white. The individual crystals rarely exceed 3 mm. in diameter ; in places, however, masses up to 3 inches across composed entirely of interlocking fluorspar crystals occur in the vein.

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* Shand, S. J.—"The Geology of the Pilansberg (Pilaan's Berg) in the Western Transvaal." *Trans. geol. Soc. S. Afr., XXXI*, 1928, *p.* 154.

Many samples of ore from the dumps were examined by Mr. J. E de Villiers, who reports that the fluorspar rock "contains more or less evenly distributed inclusions of aegerine, apatite, felspar and small veinlets of carbonate. The rock varies with respect to grain size and degree of alteration of the pyroxene. In some specimens the pyroxene is almost entirely changed to iron oxide. The inclusions are *small* and especially in the case of the pyroxene, lath-like. Carbonates, clayey matter, and iron oxides are also unequally distributed through the samples. Small amounts of pyrite are present in a few specimens."

An examination of thin sections of the rock suggested that the paragenetic order was : apatite–felspar–aegerine–fluorspar–carbonate.

A grab sample of the fluorspar rock from the dumps and the quarry itself was submitted to the Minerals Research Laboratory and the report on it was as follows :—

(i) *Chemical analysis*—

CaF_2......... 66·9 per cent.
P_2O_5......... 2·4 per cent.

(ii) *Dressing tests.*

Preliminary crushing tests determined that the liberation of the fluorspar particles is not sensibly complete above 36 mesh B.S. screen. This fact, in conjunction with the very small difference in specific gravity of the constituent minerals, renders the utilisation of gravity methods of separation impracticable.

Flotation tests were therefore attempted to ascertain whether a saleable product could be produced.

A batch sample was ground to 100 mesh and flotation experiments were made with the addition of 0·5 ℔. Oleic acid and 0·08 ℔. ton of Pinus Sylvestris oil to provide as high grade a concentrate as possible with some sacrifice of recovery. The concentrate so obtained was given a double recleaning in a dilute pulp without any further addition of reagents. The final concentrate gave the following results on analysis :—

CaF_2.................. 70·7 per cent.
P_2O_5.................. 2·7 per cent.

Experiments in previous investigations have shown that, although apatite is rather more readily floatable than fluorspar, no form of preliminary treatment results in an appreciable elimination of apatite prior to fluorspar concentration. The tests now carried out have further confirmed this contention.

The concentrates obtained from the Wydhoek samples do not meet with the specifications for marketable fluorspar and it appears very unlikely that they would be accepted by buyers. There remains the possibility that a limited local-market might be found for hand-cobbed and hand-picked ore partially crushed and screened. By this means a tendency for fluorspar concentration in the oversize product has been noted but with very low recovery. The only possible market for this material might be the local steel industry if they would accept a product of such low grade.

Mr. Denton, the owner of the farm Wydhoek, recently located another deposit lying immediately over the crest of the ridge on the opposite side of the valley, south of the first deposit. Here coarsely-crystalline fluorspar occurs as a narrow vein in weathered fine-grained alkali lava. The vein ranges in width from 7 to 9 inches, strikes 60° E. of N., dips to the N.W. at angles of from 60° to 80°, and has been proved for a strike of 150 feet by eight shallow prospecting trenches. In one place the vein is differentiated; 6–7 inches adjacent to the footwall are coarsely crystalline, while the 2–3 inches adjacent to the hanging wall are fine-grained.

Although the fluorspar appears to be of a fairly high quality the thinness of the vein and its inaccessibility preclude successful economic exploitation.

(*b*) *Nooitgedacht* 748.—According to Shand, a deposit in the lavas of the Pilansberg was mined on this farm in 1925.

(*c*) *Buffelskloof* 219.—At least three deposits are known to occur on this farm. One is on an abandoned stretch of road a little to the east of Mr. Roets's homestead. An east-west trench about 100 feet long and 1 to 3 feet deep was dug in the road, but only a single stringer of fluorspar one-quarter inch thick was exposed in the country syenite. A small quantity of fluorspar, however, is alleged to have been extracted from the subsoil at this place.

Somewhat nearer to the homestead there is a partially collapsed trench from which fluorspar is stated to have been taken.

According to Mr. Roets another deposit occurs near the top of the range of hills south of his homestead. (L. E. K.)

2. WALMANSTHAL 116, PRETORIA DISTRICT*

Massive purple to almost black fluorspar, in intimate association with apatite and a little pyrite, is found on the north-western side of the farm Walmansthal 116. This fluorspar body, measuring about 150 by 50 yards, occurs in Rooiberg felsites very near their contact with a strip of slightly younger agglomerate. Lombaard considered the fluorspar-apatite rock to be genetically related to an occurrence of foyaite three-quarters of a mile to the south-west.

Chemical analysis showed that in the rock the ratio of fluorspar to fluor-apatite is about 3 to 1, and as the apatite crystals average only 1 to 5 mm. in length and 0·5 mm. in width, economic separation is not practicable.

3. LEEUWFONTEIN 320, PRETORIA DISTRICT

An irregular lenticular vein of fluorspar occurs in a white, highly felspathic syenite of the Leeuwfontein alkaline complex.

In a small prospecting pit 15 feet deep, the vein is 8 feet wide, strikes N.N.W. and dips to the east almost vertically. It can be followed for only about 40 feet, and where it disappears under the overburden it is only 2 feet 9 inches wide. Other thin veins occurring in the vicinity are also lenticular and none exceed 6 inches in thickness.

The fluorspar is for the most part fine- to medium-grained and deep purple in colour, save on the outcrops where it has been bleached. Large crystals, up to 10 cm. across, are sometimes encountered. Much pale greenish fluor-apatite is present and, near the eastern contact of the vein, is so plentiful that the rock has a streaky appearance In addition to apatite there are also specks of pyrite, and less commonly chalcopyrite, limonite and thin films of opal.

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* Lombaard, B. V.—"Fluorite-Apatite rock from Walmansthal No. 116." *Trans. geol. Soc. S. Afr.*, *XXXII*, 1929, *pp.* 159–164.

Approximately 50 tons of fluorspar were lying at grass in 1941. In view of the lenticular nature of the vein, the high apatite content, and the presence of sulphides, the occurrence is considered to be of no economic importance.

The red syenite (umptekite), which is intrusive in the white syenite, contains fluorspar both as an accessory mineral and in the form of veinlets. It seems probable, therefore, that the vein is genetically related to the red syenite. (L. E. K.)

III. OCCURRENCES IN THE REST OF THE UNION AND IN SOUTH WEST AFRICA

Very little is known of the fluorspar occurrences in the rest of South Africa and South West Africa. This chapter consists mainly of extracts from reports by W. Kupferbürger, D. J. L. Visser, P. G. du Plessis, J. T. Wessels and C. M. Schwellnus.

A. ZULULAND*

Here fluorspar has been found in a series of vertical or nearly vertical veins in all types of country rock except Ecca and Karroo dolerite. On Rabe's claims, north of Hlabisa, it occurs in Old granite, and on Haupt's claims, south of Hlabisa, in Dwyka tillite, sandstone and shales. (Fig. 10.)

" The age of the deposits is therefore definitely post-Dwyka. Unfortunately, there are no exposures of fluorspar veins either in rocks of the Ecca series or in dolerite, so that it is not possible at present to fix any definite upper limit to the age of the fluorspar veins.

" The stratigraphic range from Old granite through Table Mountain sandstone and Dwyka of the country rocks in which the fluorspar veins occur, cannot be taken as any indication of the possible vertical range of the veins, for in view of their relatively late age and the subsequent geological history of the area, the structural relationships of the various above-mentioned formations must have been approximately the same at the time of their formation as they are at present. They are true fissure veins, and it is clear that the fluorspar and subordinate amounts of quartz constituting the veins were deposited in open fissures.

" Sufficient prospecting work has not been done to prove either the lateral or vertical persistence of the veins. The distance between the most northerly and most southerly exposures of the veins in the direction of their strike, which is consistently within 10° of magnetic north-south, is about twelve miles.

" There are several veins or rather veined zones, and the persistence of any one of them has not been proved over that entire distance. The greatest length over which probable continuity has been indicated by the work done at the time of my visit [1933] is at most half a mile.

" With regard to vertical persistence nothing definite can be stated, as the deepest working at the time of my visit was 90 feet at Rabe's workings, where the veins occur in the granite.

" The veins have clearly not been formed along any major dislocations, so that it is unlikely that they will extend without interruption to any great depth below the present surface.

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* KUPFERBÜRGER, W.—" Fluorspar Veins, near Hlabisa, Zululand." *Trans. geol Soc. S. Afr., XXXVII*, 1934, *pp.* 87–96.

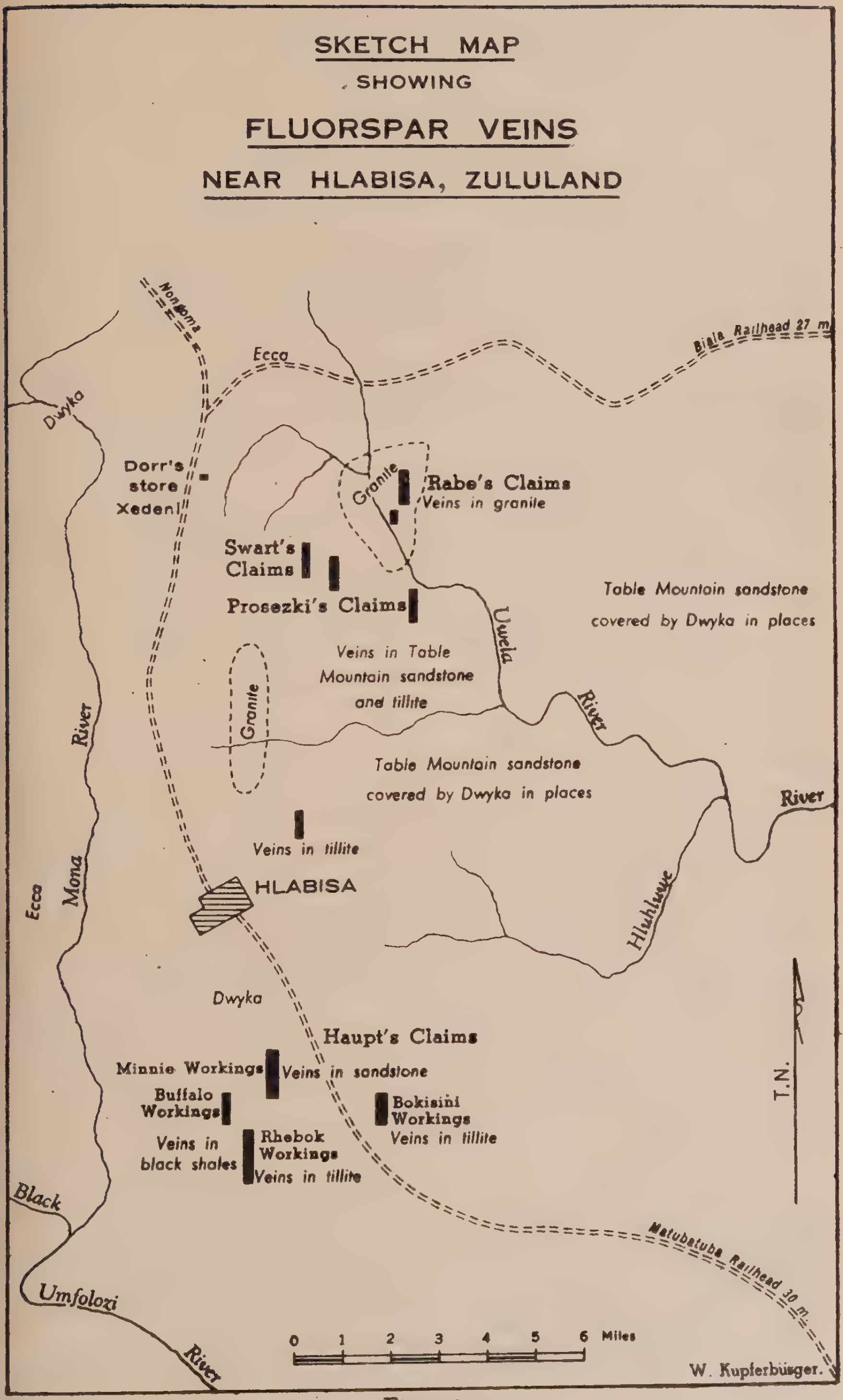
SKETCH MAP
SHOWING
FLUORSPAR VEINS
NEAR HLABISA, ZULULAND
Nongoma
Ecca
Dwyka
Bivla Railhead 27 m.
Dorr's store Xedeni
Granite
Rabe's Claims
Veins in granite
Swart's Claims
Prosezki's Claims
Uwela
Table Mountain sandstone covered by Dwyka in places
Veins in Table Mountain sandstone and tillite
Granite
River
River
Table Mountain sandstone covered by Dwyka in places
River
Veins in tillite
HLABISA
Mona
Ecca
Hluhluwe
Dwyka
Haupt's Claims
Minnie Workings
Veins in sandstone
Buffalo Workings
Bokisini Workings
Veins in tillite
Veins in black shales
Rhebok Workings
Veins in tillite
T.N.
Black
Umfolozi
River
Matubatuba Railhead 30 m.
0 1 2 3 4 5 6 Miles
W. Kupferbürger.

Fig. 10

"At Rabe's workings there is a brecciated zone cutting across the direction of strike of the fluorspar veins in a N.N.E.–S.S.W direction, in which fluorspar has been deposited as cementing material and at Haupt's 'Minnie' workings irregular fragments of sandstone are to be found in one of the veins, but there is no evidence of displacement of the strata on either side of the veins.

"The walls of the veins are generally straight and well-defined, and there is no evidence of metasomatic replacement of the wall rock by fluorspar or quartz. The veins in the granite at Rabe's workings occasionally have small tongue-like offshoots a few inches wide at the base and tapering to a point into the adjoining granitic walls, but this feature was not noticed in any of the veins cutting the Table Mountain sandstone or Dwyka rocks.

"The width of the zones containing groups of parallel veins of fluorspar ranges from 20 feet downwards. At Haupt's 'Minnie' workings, the only occurrence which has been opened up sufficiently to reveal the structure clearly, there are at least fifteen such veins ranging in width from fractions of an inch to over two feet. The thickness of individual veins is by no means consistent laterally, and varies considerably over comparatively short distances. Wherever the veins have been explored it has been found that they diminish in width gradually, but consistently, from the surface downwards. The narrow straight-walled vertical fissures in which the fluorspar was deposited display a remarkable degree of similarity to the fissures formed in calcareous sandstones at St. Lucia Bay during the Zululand earthquake of December 31st, 1932.*

"The mineralogy of the veins is comparatively simple, and fluorspar and quartz are the only minerals present. In some cases quartz may be entirely absent or present only as a thin selvedge of pure chalcedonic quartz. In other cases it occurs in well-formed crystals up to 1 cm. in length lining the walls of the fissure, which is then filled with fluorspar. In places the veins show signs of having been affected by later movements, resulting in the reopening of the fissure along one wall and the further deposition of quartz and fluorspar.

"In other veins there is evidence of intermittent deposition of quartz and fluorspar in the markedly composite structure of vein-quartz alternating with fluorspar several times. At one locality, Haupt's 'Rhebok workings', the fluorspar is cut by a branching network of fine-grained chalcedonic quartz veins, which indicates a possible shattering of the vein by the subsequent infiltration of silica-bearing solutions.

"The fluorspar of the vein is generally coarsely crystalline, and displays crustification both in crystallisation and in colour banding parallel to the walls of the vein. This latter feature is well displayed in some of the veins in which the crystallisation is relatively coarse, notably in one occurrence opened up about 1 mile N.E. of Hlabisa, where in a vein 4 to 6 inches wide the outer portion, about 1 inch wide, is pale green and the inner portion pale mauve in colour. This colour banding is best displayed in the fine-grained purple banded fluorspar from the upper portions of one of the veins at Rabe's main workings. Here the fluorspar was deposited in relatively fine-grained form along an undulating fissure wall, and is beautifully banded in varying intensities of purple. It is of particularly striking appearance in sections cut across the banding. In some cases the veins are not completely filled, and the open spaces along the middle of the veins are lined with well-formed cubic crystals of fluorspar. The crustification and the presence of open spaces in the veins indicates that the veins were formed by deposition along the walls of open fissures under conditions of relatively light load and close to the surface.

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* Krige, L. J., and Venter, F. A.—"The Zululand Earthquake of the 31st December, 1932." *Trans. geol. Soc. S. Afr., XXXVI*, 1933, *pp.* 101–112.

" When looking for a possible cause of the formation of the fissures and the origin of the fluorspar and quartz, it is significant that both the location and strike of the veins conform to that of the axis of the Lebombo monocline extended southwards. It is not unlikely that these fissures are some of the minor effects accompanying the formation of the Lebombo range.

"According to du Toit* the crustal warping which produced this feature occurred during the period of eruption of the Lebombo volcanics, and, furthermore, that the optimum was reached during the Middle or Rhyolitic period of volcanicity. It may therefore be possible to attribute the fissures to the earth-movements, and mineralising liquids and gases to the acid magma which gave rise to the great quantities of rhyolitic lava and related acid intrusives of that period."

Analyses.†

	Selected Sample.	50 lb. Sample Sorted.	Bulk Sample from Sorting Floors.
CaF_2	98·59	98·42	98·38
$CaCO_3$	0·75	0·45	0·41
SiO_2	0·24	0·40	0·74
Fe_2O_3	Trace	Trace	Trace

ECONOMIC CONSIDERATIONS

". . . In spite of the association of quartz with fluorspar in the vein filling, it has been found possible by careful cobbing to obtain material of the desired purity in bulk . . . ; the wastage in cobbing operations is likely to be high, probably in the neighbourhood of 30 per cent.

" Moreover, unless crushing and some method of mechanical separation is adopted, the smaller veins of less than three inches in width will have to be disregarded in any estimate of available tonnage for the production of commercial grade ' acid lump ' fluorspar.

". . . Most of the other promising outcrops have been prospected to some extent, but the general practice of exposing only one side of the vein and the outer margins of the veined zones on both sides, instead of cutting trenches right through the fluorspar, made the estimation of the total available tonnage of fluorspar somewhat uncertain. The individual veins, where opened up, show rapid variations in width, and are limited in their lateral extent. Vertical persistence has not been proved to more than 100 feet at most, and in most cases there is a gradual narrowing down in the width of the larger veins. In view of the deep-seated origin of the fluorspar however, it is highly probably that, although some of the veins exposed near the surface may eventually pinch out, other parallel and related veins may be proved within the fissured zones and continue to greater depths.

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* " The Volcanic Belt of the Lebombo—A Region of Tension." *Trans. roy. Soc. S. Afr., XVIII*, 1929, *pp.* 189–217.

† Analyses kindly supplied by W. T. Heslop, Esq., Jan., 1934.

". . . The comparative proximity to the port of Durban of these deposits (180–200 miles by road and railway) compared with the much greater distance over which the fluorspar from the Western Transvaal has to be transported by rail to the ports, led to a good deal of optimism about the exploitation of these deposits."

In 1939 a small quantity of fluorspar was produced in the Nongoma district, Zululand. This fluorspar was mined on what were Prosezki's claims and which are now held by A. L. Pretorius. The fluorspar veins here occur in Table Mountain sandstone and in Dwyka tillite. Mr. V. H. M. Barrett, Inspector of Mines, Natal, visited the deposit in 1940 and reported as follows :—

> "There are two open cuttings about 150 feet and 50 feet long respectively on the same strike, but separated by some 50 feet of barren ground. Several piles of cobbed and uncobbed fluorspar totalling about 100 tons are lying at grass. No work has been done for some time and an examination of the workings indicates that the vein has pinched out at a depth of from 6 to 10 feet. It would appear, therefore, that this occurrence has no more promising features than those disclosed in other parts of the district."

B. North-West Cape Province

1. KAIGAS, RICHTERSVELD, NAMAQUALAND DISTRICT

In that part of northern Namaqualand known as the Richtersveld, fluorspar has been discovered about 1½ miles south-west of Kaigas. It occurs in the Kaigas limestones where these have been intruded by the younger post-Nama Kuboos granite. The samples from this locality that have been sent to the Geological Survey for identification are pure pale green and pale blue crystalline fluorspar. Some of the pieces are very nearly of optical grade.

2. ONSEEPKANS, KENHARDT DISTRICT

Fluorspar occurs on the south-western part of Onseepkans on the eastern bank of the Orange river, and about 1½ miles to the south beyond the irrigation scheme.

It is found only in a small patch about 10 to 15 feet wide and some 60 feet long in a north-south direction. The parent rock is a medium-grained, slightly porphyritic red granite. A few pegmatites, up to 3 feet in width, are encountered in the immediate vicinity, but within the area under discussion lens-like bodies of pegmatite from 1 to 7 inches thick and pegmatite veins about 1 inch thick are found. The granite is considerably weathered, due chiefly to the kaolinisation of the felspar.

The fluorspar is limited to the lens-like pegmatite bodies and the thin veins. It was the last mineral to separate and replaces mainly the felspar. Where the replacement has been strongest, fluorspar forms about half of the pegmatite mass; in most cases, however, the proportion is smaller.

The fluorspar is generally deep violet or greenish white and, as a rule, both colours are present in the same body and grade into one another.

To the north and the south the kaolinised rock passes over into the normal red granite; but in the northerly pegmatites the felspar is replaced by calcite instead of fluorspar.

The occurrence is not considered to be of any economic importance. (D. J. L. V.)

3. STYERKRAAL, KENHARDT DISTRICT

Fluorspar occurs as small irregular veins about two-thirds of the way up the north side of a small hill on the farm Styerkraal, which is situated some 20 miles east of the settlement of Onseepkans on the Orange river.

The country rock is a giant pegmatite consisting of crystals of microcline felspar up to 20 feet in length, irregular quartz masses and small aggregates of muscovite crystals.

Two pockets of fluorspar 4 yards apart occur between the microcline and quartz in this pegmatite. One is 6 feet in length, 1 to 1½ feet in width and is shaped like a horseshoe; the other is an irregular lens 3 feet in length by 1½ feet maximum width. The fluorspar is well-crystallised, colourless and pure.

Light green beryl crystals up to 2 feet across occur in the quartz of the pegmatite only 2 feet from the fluorspar lens. Another associated pegmatite mineral is gadolinite, a pocket of which was found further up the hill some 20 yards from the fluorspar bodies. The gadolinite occurs at the contact of the giant pegmatite and a medium-grained muscovite rich pegmatite.

According to Mr. G. K. Joubert fluorspar is often encountered associated with scheelite in the pegmatites of the lower Orange river valley. None of the occurrences found to date are of economic importance. (L.E.K.)

4. DYASONSKLIP, GORDONIA DISTRICT

(*a*) *Locality.*—This mineral deposit may be reached by following the main road from Upington to Keimoes for about 14 miles and then turning off to the north by the road leading to the mine of the Craylo Base Metal Syndicate. This latter road follows the eastern boundary of the farm Dyasonsklip. The deposit lies 5·9 miles from the main road, and some 200 yards within Dyasonsklip.

(*b*) *Geology.*—The country rock is a medium-grained, gray biotite-muscovite gneiss, weathering to a brownish red on the surface. Outcrops are rarely visible owing to a covering of sand and surface limestone. The area around Dyasonsklip is characterised by a number of parallel breccia veins, striking east-west and consisting mainly of quartz. These veins belong to the most recent of the vein systems in the vicinity and are possibly genetically related to the younger granites further east.

(*c*) *Mode of Occurrence.*—The fluorspar mineralisation occurred in one of these zones of brecciation. The quartz breccia is about

8–10 feet wide and the fluorspar forms the youngest infilling in tl middle of the breccia. The width of the ore vein varies fro approximately 3 feet at its widest to 1 foot or less. The outcro can be followed for some 200 yards, when it becomes covered wit sand at both ends. To the east, at McTaggart's Camp, the sar breccia is exposed at a few places, but no ore has been observed.

The fluorspar is green coloured, purple and colourless, wit a banded structure along the sides of the vein. Pyrite, azurite(? and cinnabar(?) are accessory minerals, present in small quantities.

A sample of the ore, analysed by the Government Chemic Laboratory, showed the following results :—

(i) Analysis of sample as received :—

CaF_2	98·6 per cent.
SiO_2	1·23 per cent.
Fe_2O_3	0·16 per cent.
$CaCO_3$	0·39 per cent.

(ii) Analysis of selected unweathered portion of sample :—

CaF_2	99·6 per cent.
SiO_2	0·46 per cent.
Fe_2O_3	0·20 per cent.
$CaCO_3$	0·38 per cent.

The samples for analysis were sent in by Mr. H. H. Kemp, Officer in-Charge, Mineral Development. The first analysis represents or appearing reasonably clean in the vein, the material having bee collected from various parts of the ore body. The second analysis is of selected portions from the sample used in the first test. From a comparison of the results obtained from both the tests it appears that little impurity is contained in the fluorspar as such, which means that it will be possible to separate pure fluorspar from the broken mass by hand-picking.

It is possible that similar occurrences of fluorspar may be found in the vicinity by a careful examination of breccia veins. A smaller fluorspar deposit, not of the same type as that described above, was also discovered on McTaggart's Camp, in the course of prospecting for wolfram. (P. G. du P.)

C. SOUTH WEST AFRICA

I. GARUB 83, KEETMANSHOOP DISTRICT

(*a*) *Locality.* The farm Garub 83 in the Great Kharas Mountains is some sixty miles by road north of Karasburg station. The now abandoned mine is near the boundary of this farm and Stinkdorn 28.

(*b*) *History.*[*] The Garub ore body, which is reported to have consisted of a copper-stained gossan, was discovered about 1913 by Mr. van der Bergh. No work was done until 1922, when Mr. F. L Chapman unsuccessfully attempted to work the property as a lead mine In 1928 Mr. Maxim mined galena but, owing to the sporadic distributior of the galena pockets and the erratic silver content, operations were soon suspended.

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[*] Summarised from an unpublished report by Dr. W. P. de Kock, formerly Minin Authority to the South West Africa Administration.

From January to May, 1932, Mr. T. G. Gericke sorted, screened, and washed the fluorspar on the dumps and shipped some 600 tons to the U.S.A. via Cape Town. Transport costs, however, were too high for this to pay.

Messrs. Fluorite and Minerals (Pty.), Ltd., worked the mine in 1938 and 1939. The deposit is now lying fallow.

(*c*) *Geology.* -The country rocks at the mine consist of medium- to coarse-grained porphyritic Old granite and injection breccias considered to be of post-Dwyka age. These breccias contain biotite and amphibole; coarse and usually irregular fragments of granite, granulite, aplite and diabase; and shales, quartzites, sandstones, and limestones of the Nama system. The matrix is composed largely of quartz, orthoclase, and microcline. Where associated with the granite the breccias occur both as dykes and as flows.

Injection breccia is well exposed at the entrance to the incline shaft of the mine, and it can be followed at intervals either in the walls or as rounded remnants within the fluorspar body to the water-level, a distance of 160 feet down the incline. The mineralisation took place either together with or shortly after the injection of these breccias.

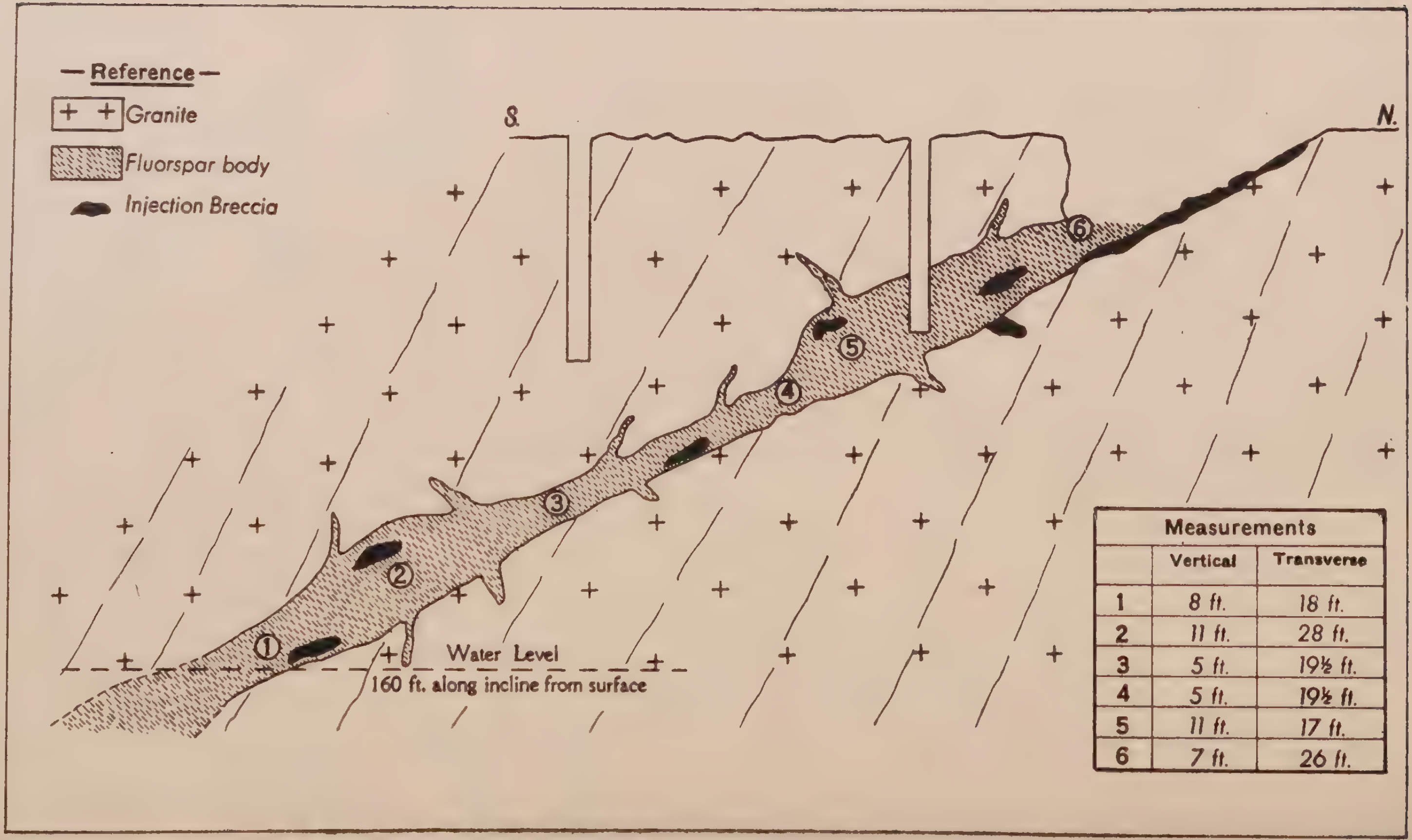
(*d*) *Mode of Occurrence.* -The fluorspar occurs in Old granite as an inclined pipe-like body, which thickens and thins somewhat irregularly, and has a general dip of about 27° in a southerly direction. The ore shows a sharp dip of about 45° at water-level, but this may be due to another irregularity in the shape of the ore body. A section across the length is either oval or lenticular. Stringers or veinlets of fluorspar sometimes penetrate the granite around the massive ore body, but generally the contact is sharp. A marked change of colour takes place from the middle of the ore body to the granite walls. The central portion of whitish to pale greenish fluorspar is surrounded by 2 inches to 4 inches of a bluish colour and half an inch to 1 inch of violet-coloured fluorspar forms the outer rim of the ore body.

Associated minerals are galena, chalcopyrite, and barite, together with oxidation products such as malachite, azurite, anglesite, and cerussite. These minerals occur in vughs or as encrustations. The lead minerals are found only in the upper parts of the mine. About 60 feet down the incline from the surface the ore is mixed with brecciated granite—a soft, friable, yellowish, clayey material, which contains almost perfect tabular crystals of anglesite measuring up to 9 inches by 4 inches by 3 inches.

A little limonite, quartz and calcite also accompany the ore.

(*e*) *Size and Possible Extension of Ore Body.*—The size of the ore body is indicated in the sketch (Fig. 11). The fluorspar was extracted by means of an inclined shaft following the ore body, and the bulk of the ore down to water-level has been stoped out. The water-level is about 80 feet vertically below the surface. All ore extracted has been removed and nothing is left on the old dump sites. Rough measurements indicated that possibly 1,900 tons of fluorspar had been mined.

The end of the ore body had not been reached when mining operations stopped. It cannot be stated how far it will extend in



Measurements		
	Vertical	Transverse
1	8 ft.	18 ft.
2	11 ft.	28 ft.
3	5 ft.	19½ ft.
4	5 ft.	19½ ft.
5	11 ft.	17 ft.
6	7 ft.	26 ft.

Fig 11.—Diagrammatic section of the Garub Fluorspar body, South West Africa

depth, but it is anticipated that a considerable tonnage of exceptionally pure ore exists at deeper levels. Before further mining operations are carried out information regarding the thickness and inclination of the ore body should be obtained by drilling.

(*f*) *Type and Quality of Ore.*—The ore is compact, massive and of exceptional purity. Samples taken some years ago by W. P. de Kock from dumps and from material being transported gave CaF_2 as varying between 99·8 per cent. and 100 per cent. When broken or fractured the fluorspar usually exhibits the typical octahedral cleavage, and the smaller granular pieces are almost invariably of irregular octahedral shapes. Impurities such as galena and chalcopyrite can be removed by hand-picking, as can also the tabular crystals of barite which are readily distinguished from fluorspar by their greater specific gravity. All these impurities, however, form a negligible part of the main ore body. Generally the material from the mine is of such purity that with a little care in blasting, hoisting and dumping, no further treatment is necessary to improve the grade.

Water-clear optical fluorspar has not been found but it is possible that some may occur here.

(*g*) *Transport and Labour.*—The nearest railway station, Karasburg, is approximately sixty miles away, and the cost of transport is thus high. Local native (Bondelswarts) labour is difficult to obtain and is of a very poor standard. (J. T. W.)

2. AUKAM 104, BETHANIE DISTRICT

On the farm Aukam 104, about thirty miles south of Kuibis siding on the Seeheim-Luderitzbucht railway line is a fluorspar occurrence. The actual prospect is three to four miles west of the homestead on the farm and about one mile east of the graphite mine.

The fluorspar deposits are confined to a little granite foothill below the slopes of a plateau, formed of the Basal beds and Kuibis quartzites of the Nama system resting unconformably on granite, which is probably the equivalent of the Older granite of the Basement complex.

The granite, greyish in colour, commonly porphyritic and in parts gneissose, contains discontinuous veins and lenses of fluorspar over an area of about 50 yards wide and 300 yards long. The general strike of the fluorspar veins is east-west, but some are inclined to this direction at various angles. The veins are as a rule almost vertical. One vein, the main deposit, had a width of over 5 feet on the surface but in one part of the trench-like excavation, at a depth of 20 feet, the width decreased to about 3 inches, while in other parts it completely petered out. In one corner of the working, however, the vein extends in the form of discontinuous narrow lenses. Druses occur in the granite, mostly in the immediate proximity of a vein. Such druses are never large and seldom measure more than a few inches across.

The numerous pits, trenches and adits prove that the fluorspar-carrying veins are discontinuous both vertically and along their strike.

The fluorspar although mostly white is commonly tinted mauve, green, pink, and light yellow. Crystals are by no means scarce and octahedra, cubes and dodecahedra have been found. Faces of more than one form are developed on many crystals.

An occasional crystal of calcite accompanies the fluorspar as gangue.

Although some 70 tons of excellent material have been mined, the fluorspar exposed in the various workings is present in such small quantities that no large-scale production can be expected. When visited in November, 1940, the deposit was lying fallow. (C. M. S.)

3. MARBURG I, OTJIWARONGO DISTRICT*

This deposit is situated on the farm Marburg 1 about 12 miles north-west of Otjikango station in the Otjiwarongo district and about 36 miles from the village of Otjiwarongo. The fluorspar occurrence is located in the Marburg mountain, a large hill of metamorphosed sedimentaries of the Damara system surrounded by granites of the Salem type. The fluorspar, which is locally associated with a very pure haematite, is light green in colour and occurs in steeply dipping parallel bands striking almost due north and south. These bands, of which there are three, are reported to have been traced over a strike of more than a mile and are individually of the order of 100 to 150 feet wide.

On the southern flank of the hill one of these bands has been opened up by means of an adit driven about 150 feet into the hillside. Near the end of this adit a winze has been sunk to a depth of 100 feet. All this work was accomplished in massive fluorspar, which indicates the extensive nature of the body.

Apart from the haematite mentioned above, the only other mineral present in quantity is quartz which is seen disseminated in certain sections of the ore body. As, however, fluorspar is principally used for fluxing the presence of quartz cannot be considered a serious drawback.

The grade of massive ore varies from about 70 per cent. to over 90 per cent. depending on the quantity of quartz. No doubt selected portions of the ore body will yield almost pure fluorspar but such rich pockets have not as yet been encountered. Benefication of the low grade ores could be tried out but will be wasteful on account of the small difference in specific gravity between the fluorspar and the quartz and the generally intimate intermixture of these two minerals.

The deposit, while not of high grade, is certainly the largest of its kind in Southern Africa and the reserves must run into millions of tons. Should there be a considerable expansion of the iron and steel industry in the Union, this deposit might be exploited.

4. KARIBIB AREA‡

Fluorspar associated with andraditic garnet, tremolite and calcite is present in pegmatite-invaded crystalline marbles and limestones of the Marble series near the Gross Spitzkoppe. The garnet rock occurs in a zone 280 yards long and from 15 to 30 yards wide and the fluorspar tends to form bands therein. Although the fluorspar is generally white in colour, it has a deep violet hue along the contact with tremolite.

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*This information was kindly furnished by Dr. W. P. de Kock, formerly Mining Authority to the South West Africa Administration.

‡ "The Geology and Mineral Deposits of the Karibib Area, South West Africa." *Expl. Sheet* 79 (*Karibib, S.W.A.*), 1942.

On Noitgedag 49 fluorspar coloured white, green and purple occurs with quartz and chalcedony in cavities along joint planes in pegmatite-invaded crystalline limestones. (P. J. Rossouw, *op. cit. p.* 125.)

5. OMARURU AREA*

A foot-wide vein of fluorspar occurs along the margin of a pegmatite in granite on Kohero West. " For a distance of 60 yards the vein carries fluorite in very varying quantities. The ore occurs in green, bluish, purple and white colours which frequently form concentric layers exhibiting colours of various tones in close sequence. Secondary quartz and calcrete are strongly admixed with the fluorite." The deposit is not of economic importance. (P. J. Rossouw and C. M. Schwellnus, *op. cit. p.* 116.)

6. WARMBAD AREA†

On the farm Platrand, about twenty miles south-east of Ariamsvlei station, fluorspar occurs together with quartz and chalcedony in a series of narrow veins in the Kuibis quartzites. " The fluorspar is found intergrown with the quartz and generally filling the central portion of the fissure. It varies from a massive type in which hardly any crystal form can be made out to perfectly crystallised cubes and octahedra of a delicate green to deep-purple colour. . . . The occurrence has no economic importance." (W. P. de Kock, *op. cit. pp.* 53, 54.)

IV. RECOMMENDATIONS FOR FUTURE DEVELOPMENT IN THE UNION

Apart from the " gravel " and " zincblende-fluorspar " deposits on the farm Buffelshoek 284, the upper and easily worked parts of the known occurrences in the Dolomite of the Marico district may be considered as practically worked out. Thus, unless new deposits are found in the Dolomite, the expanding South African metallurgical industry will have to rely to an ever increasing extent on those in the Red granite.

The reserves in the Union are estimated at three-quarters of a million tons and, in order to extend the life of the fluorspar industry as far as possible, it will be essential to work the deposits in the most efficient and economical manner. The mining methods at present employed are wasteful. In some instances country rock mixed with fluorspar is dumped on top of the ore bodies. This impedes future development and will increase costs.

Underground mining is fortunately not necessary at most of the occurrences investigated.

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* The Geology and Mineral Deposits of the Omaruru Area, South West Africa." *Expl. Sheet* 71 (*Omaruru, S.W.A.*), 1939.

† " The Geology of the Warmbad District, South West Africa." *Mem.* 2 *Dep. Min., S.W. Afr.*, 1936.

After weathering, fluorspar does not as a rule stand out fron either the Red granite or the Dolomite and, whether in a vein or a irregularly shaped body, is generally flush with the surface. Th fluorspar can readily be noticed in outcrops by its octahedral cleavag the surface being generally cut up by numerous triangles ; its dul appearance on the weathered surface, and its glassy lustre on fres surfaces.

The occurrences in the Red granite have largely formed near th contact of the granite with the felsites. Prospectors are accordingl advised to pay more attention to this part of the Red granite (D. P. v. R.)

V. PREPARATION FOR MARKET

In many of the South African deposits the fluorspar as mined i sufficiently pure to be shipped direct to the consumers, or at the most a light crushing followed by hand-sorting is all that is required t produce a saleable product. If, however, impurities such as limeston or calcite, barite, galena, sphalerite, quartz, or chalcedony are present in appreciable amounts, one or other of the following forms of treatmen may be necessary :—

(1) Crushing, washing and hand-picking.
(2) Screening.
(3) Jigging or other form of gravity concentration.
(4) Flotation.
(5) Decrepitation.

J. E. Laschinger has discussed (*pp.* 15 and 40) the application to South African fluorspar of all save the last of these methods.

Decrepitation has been used with some success in New Mexico and British Columbia. The best results were obtained when material of −8 to +15 mesh was heated to 650° C. in a rotary drier. The fluorspar on heating flies apart from the gangue and the two can then be readily separated.

In the U.S.A. treatment by flotation is becoming increasingly important, and although the process was first used commercially as recently as 1929, a decade later flotation concentrates amounted to 22,450 tons out of a total fluorspar production of 182,771 tons.* These concentrates are generally used for the manufacture of hydrofluoric acid, or in the glass and enamel industries, which require finely divided material of high purity. The middling flotation products, which are not pure enough for use in these industries, could be utilized as metallurgical spar were it not for their fine particle size. Agglomeration, by sintering pellets made up of the fines bonded by plastic diluents such as freshly hydrated lime, ferrous hydrate, plaster of paris, or sodium silicate, has recently been tried out in the U.S.A. with some success.† The sintered pellets thus produced were tested in open-hearth furnaces and proved as satisfactory as the ordinary gravel spar generally used.

When fluorspar is intimately associated with such gangue minerals as quartz, chalcedony, barite, sphalerite, and apatite, or if inclusions of pyrite, marcasite, chalcopyrite, apatite, and quartz are present;

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* *Miner. Yearb. Wash.*, 1940, *p.* 1340.

† U.S. Patent 2,184,078.

such fine grinding is required to free them that separation is not economically practicable.

At various mining propositions in different parts of the world the following minerals are also found associated with fluorspar :—celestine, wolframite, tetrahedrite, arsenopyrite, pyrite, marcasite, chalcopyrite, siderite, molybdenite, stibnite, cinnabar, cassiterite, and bismuth minerals. At some of these mines fluorspar is a by-product.

Fluorspar is an important by-product in the recovery of lead from galena-fluorspar ore bodies. In Derbyshire such ores were worked formerly only for their lead content and the fluorspar was thrown on to the waste dumps. Since 1906 large quantities of fluorspar have been recovered by screening and hand-sorting these old " waste " dumps.(2) (L.E.K.)

VI. USES

The following table shows the percentage consumption by industries in the highly industrialised United States of America :—

	Average 1932–1936.*	1938.†
Basic open-hearth steel	72·15	63·95
Electric furnace steel	3·85	3·48
Foundry	1·23	1·73
Ferro-alloys	0·44	0·69
Hydrofluoric acid and derivatives	10·33	16·43
Enamel	3·42	3·48
Glass	7·71	9·12
Miscellaneous	0·87	1·12
	100·00	100·00

In the United States the average consumption per year in the period 1932–1936 was 114,200 short tons and for the year 1938 it was 115,100 short tons.

In the Union of South Africa fluorspar is at present employed only in the metallurgical industries and to the extent of approximately 2,500 tons per annum. The rapid growth of these industries in the Union is shown by the fact that in 1918 the consumption was only 100 tons.

Metallurgical and other industrial uses of fluorspar are briefly listed below :—

A. METALLURGICAL INDUSTRIES

Fluorspar is used :—

(1) As a flux or slag conditioner in basic open-hearth steel furnaces. The fluorspar, which is shovelled on to the surface of the slag in the form of gravel or small lumps, serves not only to lower the melting point and increase the fluidity of the slag, and to flux free limestone lumps still present, but is believed by many steel experts to aid in the removal of sulphur, phosphorus and even silica from the steel. A fluid slag readily transmits the heat

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* *Miner. Yearb., Wash.*, 1933–1937.

† *Miner. Yearb., Wash.*, 1940, *p.* 1339.

of the flame to the steel below and thus reduces the time of heating. Bubbles of gas, too, can readily escape from the steel and finally, when the furnace is tapped, the fluorspar conditioned slag runs out readily.

The amount of fluorspar used per ton of steel produced has been gradually reduced in recent years from 8–10 lbs. to 5–7 lbs. In the United States the average in 1939 was 5·36 lbs.* while in South Africa the consumption by Iscor† works out at about 4·96 lbs.

Less fluorspar is required when much haematite is used to eliminate carbon or when high manganese pig is employed. If, however, dolomite is substituted for limestone, or much scrap which requires a high lime charge is used, a larger quantity of fluorspar is added. The Union Steel Corporation (of South Africa), Ltd.,† Vereeniging, which uses a great deal of scrap, consumes approximately 17 lbs. of fluorspar per ton of steel ingot.

Although good steel can be made without fluorspar, the benefits derived from its employment far outweigh the trifling extra expenditure involved.

(2) As a flux in the manufacture of alloy steels and ferro-alloys in electric furnaces.

(3) In general foundry work as a flux in the cupola or the ladle to produce sharper castings.

The Dunswart Iron and Steel Works, Ltd.,‡ Benoni, which specialises in steel castings, uses approximately one ton of fluorspar to one hundred tons of molten steel.

(4) In the reduction of aluminium from bauxite.

(5) In the production of nickel, Monel metal, and brass.

(6) In the smelting of refractory ores of gold, silver, and copper.

(7) In the smelting and refining of lead, silver, copper, and antimony.

(8) In the extraction of certain rare metals from their ores.

(9) As a flux for smelting gold and silver concentrates.

(10) As a substitute for borax in assaying. On the Witwatersrand it is used to a small extent for this purpose.

(11) In the manufacture of fluorides of iron and manganese used for steel fluxing.

B. Chemical Industries

(1) Fluorspar is the raw material used in the manufacture of hydrofluoric acid of both the anhydrous and aqueous grades. Hydrofluoric acid itself finds many uses particularly in the pickling and electro-refining of metals, in electro-plating, the etching of glassware, the purification of graphite, the testing and cleaning of diamonds, the textile and bleaching industries, the removal of efflorescences from stones and bricks, the processing of filter and special papers, and in chemical analysis. A new technological process of continuous

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* *Miner. Yearb., Wash.*, 1940, *p.* 1339.

† Information kindly supplied by the Corporation.

‡ Information kindly supplied by the Company.

production of hydrofluoric acid in furnaces of special construction has recently been developed in the U.S.S.R.(¹²)

(2) Hydrofluoric acid is used extensively in the manufacture of artificial cryolite, an essential substance in the production of aluminium, and one that is becoming increasingly important in the insecticide and enamel industries.

(3) Hydrofluoric acid is being made in increasing amounts for the producers of synthetic organic compounds such as dichlorodifluoromethane (CCl_2F_2), which is known as Freon 12 or F–12, and allied so-called " Freons " :—CCl_3F (F–11), $CHCl_2F$ (F–21), $CHClF_2$ (F–22), which are methane derivatives, and $C_2Cl_3F_3$ (F–113), $C_2Cl_2F_4$ (F–114), which are ethane derivatives.

The freons are gradually displacing the older refrigerants as they have the advantages of being non-inflammable, non-explosive, non-corrosive, and practically non-toxic.

The growing importance of the freon industry is illustrated by the fact that in 1935 nearly 2,000 tons of acid spar were used in the United States for making freons.(⁶)

(4) Other organic fluorine compounds are used as dyes, solvents, fire extinguishing agents, drugs, colour photographic materials, and insulating and cooling dielectrics for electrical apparatus such as transformers.

(5) Inorganic fluorides are also widely employed in industry. The sodium, potassium and ammonium fluorides are used mainly as insecticides and preservatives, aluminium fluoride as an insecticide, and chromium fluoride in the textile printing and dyeing industry. The ammonium, potassium and sodium bifluorides (acid fluorides) find extensive use as antiseptics, laundry sours, and in the etching of glass.

Zinc fluoride is used in insecticides and for preserving wood, barium fluoride as an antiseptic and in embalming fluids, while cerium fluoride is contained in some fog penetrating arc-lamp pencils. Boron fluoride is an excellent polymerising agent.

(6) Hydrofluosilicic acid (H_2SiF_6) and the fluosilicates are also of industrial importance. Calcium silicofluoride is utilised chiefly in the glass and enamel industries, while the silicofluorides of zinc, lead, magnesium, and aluminium are used in aqueous solutions as concrete and wall waterproof hardeners and as antiseptics. Barium fluosilicate has been employed against bagworms in the Natal wattle plantations.

(7) A solution of 32 per cent. ammonium fluoride in 20 per cent. hydrofluoric acid is known commercially as " white acid " and is used to some extent for frosting electric bulbs, etc.

C. Glass, Enamel and Ceramic Industries

Fluorspar is used :—

(1) As a source of fluorine in the manufacture of opalescent, coloured, and opaque glass. The amount of fluorspar added varies from about 50 to 500 lbs. per 1,000 lbs. of sand.

(2) As a flux and auxiliary opacifier in the opaque, white, and coloured enamels used for coating metalware.

A typical porcelain enamel or frit is made up as follows* :—

Silica	18
Potash felspar	35
Saltpetre	4
Soda ash	21
Calcite	3
Fluorspar	8
Cryolite	10
Magnesia	1
	100

The artificial fluorides of barium, zinc, magnesium, aluminium and sodium are also used as glass and enamel opacifiers.

(3) In the enamelling of bricks, tiles, art pottery and earthen cooking ware.

(4) " Fluorspar glass " is sometimes used to join glass tubes, etc., of different melting points.

D. CEMENT INDUSTRIES

The addition of 3 to 5 per cent. of fluorspar to the mix is stated to lower the sintering point, with resultant fuel economy, and to ensure the production of easily ground clinker. Becker† has stated that " proofs of any detrimental effect on cement properties produced by fluorspar have not been furnished ".

Two of the largest firms manufacturing cement in South Africa advised that they do not use any fluorspar in their processes.

E. MISCELLANEOUS MINOR USES

(1) Some manufacturers of calcium carbide and cyanamide use a little fluorspar to facilitate the fusion and contact of the constituents.

(2) As a bond in the manufacture of carbon electrodes, certain types of emery wheels, and some heat resistant bricks.

(3) As a flux in the manufacture of alundum and other artificial abrasives in electric furnaces.

(4) In rock- or slag-wool cupola operations the addition of small amounts of fluorspar reduces the viscosity of the melts, resulting in the production of finer fibres.‡

(5) In jewellery and such ornaments as paper weights, bowls, and vases. The colour is attractive but the mineral is really too soft for a gem stone. Repeated impregnation with resin is necessary when ornaments are turned or ground from " Blue John ". The finely-banded purple variety from Zululand can be made into attractive ornaments without any preliminary hardening.

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* Formula kindly supplied by the Union Enamel Co., Ltd., Durban.

† BECKER, H.—" Use of Fluorspar in Cement Manufacture." *Rock Prod.*, 30, 1927, *pp.* 83–84.

‡ MACHIN, J. S., and VANECEK, J. F.—" Effect of Fluorspar on Silicate Melts with special reference to Mineral Wool." *Rep. Invest. Ill. geol. Surv.*, 68, 1940, 15 *pp.*

F. A Note on Optical Fluorite†

Fluorite has a low index of refraction, a low colour dispersion and is isotropic. Selected specimens are transparent to a wide range of wave-lengths from far into the infra-red to deep into the ultra-violet. These properties place it in a unique position among minerals for highly specialised optical uses.

In microscopes, apochromatic objectives for correcting spherical aberration and chromatic or colour errors consist of carefully ground and polished lenses of fluorite mounted between glass lenses. The less expensive semi-apochromatic objective also contains fluorite, but unfortunately is not manufactured to any great extent owing to the shortage of high quality crystals.

Fluorite is employed for similar purposes in spectroscopes and small telescopes. In other optical instruments, where transparency to the ultra-violet and infra-red parts of the spectrum is essential, fluorite components are also introduced.

Complete crystals, or pieces bounded to a large extent by crystal faces, are more likely to prove suitable for optical uses than are massive specimens. Optical quality fluorite has, as a rule, a flat-conchoidal fracture and the tendency to cleave into octahedra is not nearly as well-marked as it is in the ordinary mineral.

Specimens for optical use must be water-clear and perfectly transparent to both the visible and adjacent invisible parts of the spectrum. They should also be quite free from cracks, incipient cleavages, striae, and inclusions. It is desirable that they should be perfectly colourless, though pieces only slightly but uniformly tinted are also in demand. The crystals should furthermore be untwinned and not exhibit anomalous double refraction. To be of any value the clear pieces should be at least three-quarter inch in diameter*, as in shaping lenses there is a loss of about 95 per cent.

Most of the optical fluorite produced at the present time comes from Switzerland, Japan, Siberia, Madoc in Ontario, and southern Illinois. A small quantity has been found in South Africa, particularly in the Oog van Malmanie deposit and at the Stavoren tin mine. Altogether about 200 ounces were recovered in 1918 and 1919 from a pocket in the central top portion of the pipe on Oog van Malmanie.

Fluorite of optical quality can occur in almost any fluorspar deposit, especially in cavities and vughs near the surface, and miners and prospectors are advised to be on the look out for it.

In opening up new deposits the use of explosives should be avoided if possible, as the shock will ruin any optical fluorite in the vicinity. The same remarks apply to the working of old deposits if there is reason to believe that material of optical grade may occur.

In order to test whether a dull-looking specimen is of optical quality or not, it should be rested on a wooden support and a corner carefully cleaved off with a knife. If the interior appears to be quite transparent or to contain transparent patches more than three-quarter inch across, it is inadvisable to attempt further trimming, as a single misdirected blow might result in the production of a network of fractures and render the specimen useless for optical purposes.

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* In referring to material of the optical grade it seems desirable to use the term fluorite and not fluorspar.

† Messrs. Adam Hilger, Ltd., London, state that crystals from which it is not possible to cut discs of at least 20 mm. diameter are of no value to them.

A convenient and rapid method of examining the interiors of these rough crystals is to immerse them in a liquid such as turpentine, which has a refractive index only slightly higher than fluorite, and view them in a bright light.

Each piece believed to be of optical quality should be separately wrapped and packed for despatch in a stout container. Careless handling of insecurely packed material may cause flaws to develop.

Although the demand by the optical trade is steady and persistent, the total amount used is stated to be less than a ton per annum.

The price depends largely on the size of the crystals. During the past few years material of average quality has fetched between \$1 and \$10 per ℔. in the United States. A single crystal from which 2 or 3 lenses are cut may realize a price corresponding to \$75 per ℔., while 25 to 30 lbs. of material offered as " optical fluorite " may be sold for only \$4 or \$5.(21)

Large, clear, and carefully annealed artificially prepared lithium fluoride crystals are said to be proving a satisfactory substitute. These have been manufactured on a commercial scale since 1938 by the Harshaw Chemical Co., of Cleveland, Ohio. There is at present no slackening of the demand for optical fluorite, and any high-grade material produced in the Union should find a ready market.
(L. E. K.)

VII. GRADING

In the grading of fluorspar both size and purity are taken into consideration. There is no definite or officially recognised system peculiar to the Union of South Africa and for the most part the American system is followed :—

A. LUMP SPAR

(Lumps $\frac{5}{8}$ inch to 6 inches in diameter)

(1) *Acid grade ;*
    1st Quality.
    2nd Quality.
(2) *Metallurgical or fluxing grade ;*
    1st Quality.
    2nd Quality.

B. GRAVEL SPAR

(Pieces $\frac{1}{2}$ inch to $\frac{5}{8}$ inch. All should pass a 1-inch ring)

(1) *Acid grade ;*
    1st Quality.
    2nd Quality.
(2) *Metallurgical or fluxing grade.*

C. GROUND FLUORSPAR

(1) *Acid grade.*
(2) *Glass-enamel-ceramic grade ;*
    Coarse.
    Fine.
    Extra-fine (Meal).

D. OPTICAL SPAR

1st Quality.
2nd Quality.

In England the term " suttings " is sometimes used for large-sized gravel spar and the coarser fines are known as " sands ".

VIII. SPECIFICATIONS

In South Africa there are no officially recognised specifications for the metallurgical or other grades of fluorspar. Buyers, as a rule, have their own specifications.

A. Metallurgical Industries

The South African Iron and Steel Industrial Corporation, Ltd. (Iscor), Pretoria, is the principal South African purchaser and takes over half the local sales. The physical and chemical specifications to which the fluorspar used by Iscor must conform* are as follows :—

> " Fluorspar in lumps 1 inch to 4 inches, having the following average analysis :—
>
> CaF_2...... 87 per cent.
> SiO_2...... 5 per cent.
> Fe_2O_3..... 3 per cent.
> Al_2O_3..... 3·5 per cent.
> $CaCO_3$..... 0·5 per cent.
> S .... trace
>
> and shall be free of phosphorus, soda, lead, zinc, and barite."

The Union Steel Corporation (of South Africa), Limited, Vereeniging, purchases about a quarter of the locally sold fluorspar and specifies* that " this material should be supplied in lumps not smaller than half an inch, and should contain a minimum calcium fluoride (CaF_2) content of 92 per cent.".

Another large consumer, the Dunswart Iron and Steel Works, Limited, Benoni, states that the following specifications† are laid down :—

> " CaF_2.......... 94 per cent. (minimum).
> SiO_2............ 4 per cent. (maximum).
> Fe_2O_3, Al_2O_3, PbS, ZnS = remainder.

The size is preferably between ½ inch and 1 inch. If bigger lumps are supplied it necessitates crushing ".

Metallurgical fluorspar should not contain much fluorspar " sand " as fine-grained material cannot readily sink through the slag and is thus wasted, and furthermore a large percentage is lost in the furnace draft.

For metallurgical uses calcium carbonate in fluorspar is only a diluent ; nevertheless buyers usually insist on a low $CaCO_3$ content, as it is uneconomic to purchase limestone at fluorspar prices. Granite, sandstone, shale, clay, sand, felspar, etc., are also diluents and are not objectionable if they are present in small amounts only.

Silica, too, is a diluent, but as it is not a flux requires fluorspar to fuse it. It has been determined that for every part of silica 2½ parts of fluorspar are needed for this purpose. Thus fluorspar averaging 90 per cent. CaF_2 and 5 per cent. SiO_2 contains in effect only 77½ per cent. available calcium fluoride. If much silica is present more lime must be added to maintain the basicity of the slag. An excessive amount of silica is thus a highly objectionable impurity in metallurgical fluorspar.

Barite is generally regarded as a harmful impurity because it contains sulphur and also tends to increase the viscosity of the slag, thus opposing the purpose for which fluorspar is added. One part of fluorspar will flux 1½ parts of barite. A small amount of barite, however, will add practically nothing to the sulphur content of the steel and will have a negligible effect on the fluidity of the slag.

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* Information kindly supplied by the Corporation.

† Information kindly supplied by the Company.

In general, sulphides such as pyrite, sphalerite (zinc blende), and galena, metallic sulphates and carbonates and also apatite are harmful impurities and, if present in appreciable amounts, may render the fluorspar unsaleable for metallurgical uses.

B. Chemical Industries.

Chemical manufacturers require fluorspar of a very high grade and usually specify a minimum of 98 per cent. CaF_2, and a maximum of 1 per cent. for both $CaCO_3$ and SiO_2.

Calcium carbonate is an objectionable impurity as it reacts with sulphuric acid, causing undesirable foaming. Silica is even more deleterious, for it combines with the hydrofluoric acid to form hydrofluosilicic acid, and for every part of silica present about 4 parts of fluorspar and 5 parts of sulphuric acid of 66° B are wasted.

Barite and metallic minerals such as galena and sphalerite are also undesirable impurities.

For the chemical industries fluorspar has generally to be supplied ground to about 80 to 100 mesh.

The fluorspar mined in the Marico district is of exceptional purity and the material exported averaged 98 per cent. CaF_2 and less than 1 per cent. SiO_2. Some shipments to the United States averaged 99·6 per cent. CaF_2. The Garub Mine, S.W.A., produced even purer fluorspar. Material of such grade is eminently suitable for the making of hydrofluoric acid and its derivatives.

Hydrofluoric acid is not at present manufactured in the Union of South Africa.

C. Glass, Enamel and Ceramic Industries

Manufacturers of opalescent glass and enamels generally require fluorspar meeting with the following physical and chemical specifications :—

Retained on 100 mesh sieve	1
Retained on 200 mesh sieve	14·5
Passing 200 mesh sieve	84·5
	100·0

CaF_2 at least	95–98 per cent.
SiO_2 not exceeding	3 per cent.
$CaCO_3$ not exceeding	1 per cent.
Fe_2O_3 not exceeding	0·1 per cent.

Practically free of Pb, Zn, Mn, S, and Ba.

Silica is merely a diluent, but calcium carbonate is harmful if present in excess of 1 per cent. as it tends to make the glass or enamel brittle. Iron oxides and carbonates are by far the most deleterious impurities, for even small amounts give glass or white enamels undesirable green or yellow-brown tints. Iron oxides and carbonates are so objectionable that many manufacturers insist that the ground fluorspar be practically snow white and reject consignments of even pale yellow and brown colour, or those having black specks of galena.

The latter is undesirable as expensive oxidising agents are required to neutralise its effects.

Opalescent glass is not at present manufactured in South Africa, and the firms enamelling ironware apparently use imported frits (porcelain enamels). (L. E. K.)

IX. WORLD PRODUCTION

The annual world production of fluorspar in recent years has generally been in the vicinity of half a million tons. Although the mineral is mined in about 20 countries, only 7 produce more than 10,000 metric tons per annum.

Country.	1923.*	1937.†
	Metric Tons.	Metric Tons.
United States of America	109,939	164,409
Germany	24,568	144,459
U.S.S.R.	—	70,000‡
France	12,913	51,430
United Kingdom	49,818	42,837
Italy	3,362	13,385
Chosen (Korea)	Nil	11,000
Newfoundland	Nil	8,479
Union of South Africa	10,975	3,615
Norway	—	1,692
Tunisia	—	1,676
Minor producers	126	2,851
TOTALS	211,701	516,000‡

* *Miner. Res. U.S.*, 1925, *Pt.* 2, *p.* 24.
† *Miner. Yearb., Wash.*, 1940, *p.* 1348.
‡ Estimate.

X. SOUTH AFRICAN PRODUCTION

A. TRANSVAAL

I. OCCURRENCES IN DOLOMITE, MARICO DISTRICT

Farm and District.	Company.	Year.	Production.	Value of Sales.
			Short Tons.	£
Buffelshoek 284 and Witkop 288, Marico district	Western Quarries Ltd.	1925	5,477	—
		1926	2,332	—
		1927	1,787	—
		1928	1,267	—
		1929	2,094	—
		1930	1,577	—
		1931	2,389	—
		1932	1,234	—
		1933	498	—
		1934	1,615	—
		1935	1,070	—
		1936	588	—
		1937	12	—
			21,940	
Oog van Malmanie 101, Marico district	Western Quarries Ltd.	1924	5,533	—
		1925	1,199	—
		1926	2,309	—
			9,041	

2. OCCURRENCES IN THE RED GRANITE

Farm and District.	Company.	Year.	Production.	Value of Sales.
			Short Tons.	£
Tooyskraal 282, Waterberg district	Mabula Fluorspar Co...	1926	950	425
	Johnson Co............	1926	300	670
		1927	1,901	3,906
		1928	1,719	3,487
		1929	760	1,520
	Fluorite and Minerals, Ltd.	1935	865	1,162
		1936	846	800
		1937	237	266
			7,578	12,236
Ruigtepoort 1373 (Goudkoppies), Waterberg district	Warmbaths Fluorite Syndicate	1929	200	400
		1930	241	482
	Fluorite and Minerals, Ltd.	1936	500	430
		1937	1,180	1,520
		1938	3,626	7,474
		1939	6,826	14,881
		1940	3,160	5,639
			15,733	30,826
Slipfontein 528, Rustenburg district	Fluorite and Minerals, Ltd.	1939	862	1,783
		1940	2,453	4,827
			3,315	6,610
Grobbelaars Hoek 785, Potgietersrust district	Fluorite and Minerals, Ltd.	1938	77	228
	James Martin and McGill	1939	64	204
			141	432

3. TOTAL PRODUCTION IN THE TRANSVAAL

Year.	Production.	Sold.	Value.
	Short Tons.	Short Tons.	£
1918..........	60	60	380
1919..........	170	170	400
1920..........	3,200	3,200	4,000
1921..........	60	60	180
1922..........	535	535	785
1923..........	12,098	12,098	16,169
1924..........	11,235	11,235	17,817
1925..........	5,383	5,383	9,016
1926..........	9,263	9,263	17,223
1927..........	8,358	8,358	16,536
1928..........	6,153	6,153	12,086
1929..........	2,993	2,993	6,040
1930..........	1,675	1,675	3,477
1931..........	2,422	2,422	5,774
1932..........	1,241	1,382	3,137
1933..........	449	491	1,003
1934..........	1,615	1,460	2,221
1935..........	2,183	2,155	3,167
1936..........	3,443	2,674	3,733
1937..........	3,985	3,574	5,777
1938..........	5,220	5,207	12,705
1939..........	11,352	10,724	24,822
1940..........	8,100	6,963	17,205
	101,193	98,235	183,653

For period 1918 to 1931 sales taken as production as no figures of production are available.

In both 1918 and 1919 the production included 100 ounces of optical spar valued at £20.

B. NATAL

Year.	Production.	Sold.	Value.
	Short Tons.	Short Tons.	£
1932	100	70	125
1934	124	75	165
1939	26	—	—
1940	80	32	104
	330	177	394

These production figures were compiled in the office of the Government Mining Engineer, Johannesburg.

C. SOUTH WEST AFRICA

GARUB, KARASBURG

Year.	Production.	Exported.	Value.	Destination.
	Short Tons.	Short Tons.	£	
1924	100	Unrecorded	Unrecorded	—
1928	9	,,	,,	—
1929	60	,,	,,	—
1932	600	,,	£3/ton	U.S.A.
1938	645	317	1,213	Philadelphia, U.S.A.
1939	116	111	308	,,
1940	291	Nil	Nil	—
TOTAL	1,821			

Figures supplied by Inspector of Mines, Windhoek. Where a particular year is not shown in the table, it signifies that neither production nor sales took place in that year.

D. TOTAL PRODUCTION IN THE UNION AND SOUTH WEST AFRICA

The total production of fluorspar in the Union and South West Africa, up to and including 1940, was 103,344 tons.

XI. THE SOUTH AFRICAN EXPORT TRADE IN FLUORSPAR

As inspection of the histogram (Fig. 12) will show, the fluorspar industry in South Africa depended until comparatively recent years almost entirely upon exports. The fluorspar mined in the Marico district was of such exceptional purity that it found a ready market in the United States for the manufacture of hydrofluoric acid and its derivatives. The importation of acid grade spar has long been encouraged by the United States Government, and as from January 1st, 1939, the import duty on shipments containing more than 97 per cent. CaF_2 was further reduced to \$3·75 per short ton, while those containing less than 97 per cent. CaF_2 are liable to a duty of \$7·50.

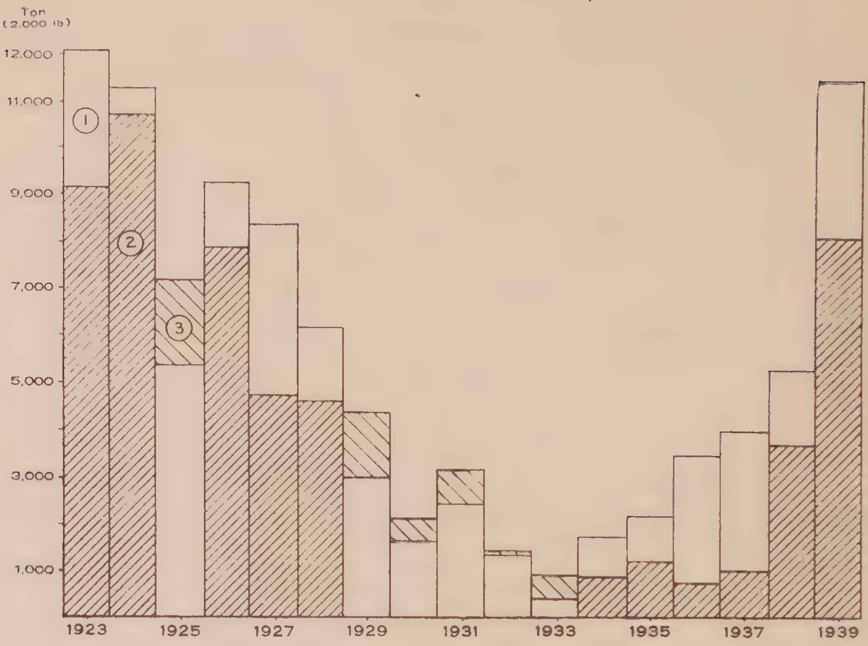

Fig 12.—Fluorspar Production and Exports 1923–1939
(Note in 1925 and the period 1929–1933 exports exceeded production.)

The upper parts of the deposits in the Marico district and the Garub Mine, S.W.A., from which fluorspar averaging 98 per cent. CaF_2 was exported, are now practically exhausted and the acid grade spar remaining will doubtless be essential in a few years' time for the growing South African heavy chemical industries, and should therefore be conserved.

The bulk of the fluorspar produced in the Union now comes from deposits in the Red granite. Samples from the largest of these, on the farm Ruigtepoort 1373, were recently analysed by the Government Chemical Laboratories, Johannesburg :–

	% CaF_2.	% SiO_2.
Lump spar from dump..........	81·0	4·2
Gravel spar from bin............	84·5	6·9
Gravel spar as shipped to a local buyer........................	86·1	5·2

Some of the fluorspar from this mine, therefore, is barely of the metallurgical grade and without treatment could not be used in the chemical and ceramic industries.

Since 1938 large quantities have been sold to Japan and in 1939 Japan took the whole of South Africa's exports, amounting to 8,038 tons. In 1940 and 1941 notable amounts were shipped to India. This recently exported fluorspar is first-grade metallurgical spar, averaging 94 to 95 per cent. CaF_2 and 1 to 2½ per cent. SiO_2.

The large scale export of fluorspar from South West Africa commenced in 1938, when 317 tons out of a total production of 645 tons were shipped to the United States. The following year the production fell to 116 tons, of which 111 were exported, again to the United States. (L. E. K.)

EXPORTS OF FLUORSPAR FROM THE UNION OF SOUTH AFRICA DURING THE PERIOD *1923-1939.†

Quantities in tons of 2,000 lbs. Values in pounds (£) in brackets.

	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	TOTALS
United Kingdom	—	—	—	—	—	—	—	—	1 (14)	—	—	—	— (6)	—	—	32 (120)	—	33 (140)
Southern Rhodesia	—	—	—	—	—	—	—	—	—	—	—	—	— (1)	1 (7)	2 (16)	13 (55)	—	16 (79)
Australia	241 (740)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	58 (126)	—	299 (866)
Canada	2,143 (5,892)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2,143 (5,892)
India	—	—	—	—	—	—	5 (15)	—	—	—	—	—	—	—	—	—	—	5 (15)
Belgian Congo	—	—	—	—	—	—	—	—	—	—		—	—				— (1)	— (1)
Denmark	—	—	—	—	—	—	—	—	24 (120)	—	—	—	—	—	—	—	—	24 (120)
Germany	—	—	— (3)	—	—	—	—	—	— (100)	— (120)	—	—	—	—	—	—	—	— (223)
United States of America	6,802 (18,710)	10,722 (34,223)	7,162 (21,627)	7,856 (20,850)	4,621 (12,354)	4,603 (11,354)	4,259 (10,760)	2,138 (6,787)	3,133 (8,430)	1,283 (4,140)	722 (2,418)	906 (2,035)	1,234 (2,753)	783 (1,602)	1,015 (2,696)	1,197 (2,671)	—	58,436 (163,589)
Japan	—	—	—	—	114 (300)	—	116 (300)	—	—	170 (568)	224 (750)	—	—	—	—	2,386 (5,446)	8,038 (19,057)	11,048 (26,421)
TOTALS—																		
Tons	9,186	10,722	7,162	7,856	4,735	4,603	4,380	2,138	3,158	1,453	946	906	1,234	784	1,017	3,686	8,038	72,004
£	25,342	34,223	21,630	20,850	12,654	11,533	11,075	6,787	8,664	4,828	3,168	2,035	2,760	1,609	2,712	8,418	19,058	197,346

* Prior to 1923 fluorspar was not listed separately.

† The Geological Survey is not permitted to publish more recent statistics.

Information compiled from the Annual Statements of the Trade and Shipping of the Union of South Africa, issued by the Department of Customs and Excise, Pretoria.

XII. SUPPLIERS OF FLUORSPAR IN SOUTH AFRICA

Fluorite and Minerals (Pty.) Ltd., 226, Maritime House, Loveday St., Johannesburg.

Abdullah Sulliman's Fluorspar Workings, P.O. Kaffirskraal, Marico district, Transvaal.

Ore and Metal Co. (Pty.), Ltd., P.O. Box 3548, Johannesburg.

F. W. Armstrong, Ltd., P.O. Box 325, Johannesburg.

Fluorspar Export (Pty.), Ltd., Witkop, P.O. Ottoshoop, Transvaal.

XIII. PRINCIPAL PURCHASERS OF FLUORSPAR IN SOUTH AFRICA

South African Iron and Steel Industrial Corporation, Ltd., Pretoria.

The Union Steel Corporation (of South Africa), Ltd., Vereeniging.

Dunswart Iron and Steel Works, Ltd., Benoni.

African Iron and Steel Products (1926), Ltd., Germiston.

Frank Martin and Co. (Pty.) Ltd., Germiston.

The Standard Brass, Iron and Steel Foundries, Ltd., Benoni.

Eagle, Brass and Iron Foundry (Pty.), Ltd., Germiston.

East Rand Engineering Co., Ltd., Germiston.

Brass and Iron Foundries in various parts of the country.

XIV. RULING PRICES

The average price per short ton f.o.r. realised from local sales in the Union was £1. 14s. 2d. during the period April–June, 1940, and £1. 18s. 9d. for the same period in 1941. For the same quarters the f.o.b. values of the fluorspar exported were £2. 12s. 2d. and £2. 18s. 9d. respectively.

In the United States the ruling price in June, 1942, for metallurgical grade Illinois and Kentucky fluorspar was \$25 per short ton, and for the acid and ground ceramic grades in bulk \$35 and \$34 respectively, all f.o.b. mines. (L. E. K.)

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